RESIDUAL HETEROZYGOSITY IN TWO VARIETIES OF UPLAND COTTON (*GOSSYPIUM HIRSUTUM* L.) AS MEASURED BY MICRONAIRE, LINT PER CENT, PER CENT FIRST HARVEST, AND YIELD OF LINT

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INTRODUCTION

Most varieties of cotton have been developed from plant selections made within existing varieties. There is ample evidence to indicate considerable genetic variance has existed in most cotton varieties in the past. However, controversy has arisen as to the amount of genetic variability remaining within existing varieties.

An estimate of residual heterozygosity should indicate if progress could be made by selecting (breeding) within a variety or if hybridization should be employed to increase genetic variability.

The primary objective of this study was to determine the amount of genetic variability, for Micronaire value (fiber coarseness or fineness), lint per cent, per cent first harvest, and yield of lint, remaining in two varieties of cotton developed in Oklahoma. It was also deemed desirable to determine the heritability of these four characters.

REVIEW OF LITERATURE

Studies of Residual Heterozygosity

According to Warner (29) Johannsen was one of the first to study variability in plants. His classic experiments with beans indicated the variability within lines of this self-fertilized crop was environmental. He selected extreme individuals within a line and found their progenies' mean regressed to that of the parental line.

There is controversy as to the amount of genetic variability in upland cotton and other crops. Sprague (27) indicates some workers may have failed to detect genetic variability in corn because of unrefined statistical techniques. Simpson and Duncan (25) made the following statement about genetic variability in upland cotton: "Natural cross-pollination occurs frequently in cotton, thus, these varieties contain much genetic variability even after many years of development and commercial use."

Their study consisted of selecting within self-pollinated varieties of cotton for yield, lint length, lint per cent, strength index, lint index and weight per one-hundred seed. Their data were taken from self-pollinated second, fourth, and seventh generation plants grown during the same season. They concluded that most of the genetic variability had been eliminated by the fourth generation. However, there was still a large standard deviation for the distribution of individual values

through the tenth generation. The authors believed this variation to be environmental and not genetic.

Manning (14, 15) estimated genetic variances between first, second and third generation progenies originating from a single plant. The genetic variability of strains and progenies within strains was estimated from the variance components of tests run over six years. The error mean square for plots was subtracted from the mean square for progenies and the difference divided by the number of replications. This numerical value was his estimate of genetic variance. The estimates of genetic variability did not decline at the rate expected. If genetic variability had been reduced one-half each generation, as would have been expected with inbreeding, in five generations it should have been reduced to one-thirty-second of the variance for the S_1 generation. In this study the genetic variance for lint per seed (the character he considered most reliable) was reduced by approximately two-thirds at the end of the fifth selfed generation. However, the ratio of strain to progeny variance was close to the expected value.

Variation was found to exist within eight commercial varieties of upland cotton by Humphrey (10). The parent varieties were phenotypically uniform as to plant type. However, they were not uniform as to fiber properties. He compared the ranges and coefficients of variability of staple length and lint per cent of parent varieties to their self-pollinated progeny through the S_7 generation. The amount of variability decreased rapidly from the parental to the S_2 generation. From the S_2 generation through the S_7 there was little reduction in variability. He concluded the original varieties were heterozygous for the characters studied but quickly segregated into homozygous lines.

Green (7) found a wide range of variability in six characters studied in upland cotton. He measured lint length, fineness, strength, seed index, lint index and lint per cent in more than 360 strains and varieties of upland cotton. The frequency distribution for all six characters approached a normal curve. He concluded from these findings that upland cotton contains an important amount of genetic variation.

Considerable variation for resistance to bacterial blight caused by Xanthomonas malvacerum has been found in upland cotton varieties by Brinkerhoff et al (2). Tolerant plants were also found. The frequency of tolerant and resistant plants ranged from 1 in 414 to 0 in 25,726 with 10 of 18 varieties having some resistant or tolerant plants. Three genes for resistance have now been isolated from these stocks (9).

Miller et al (17) estimated genetic and environmental variances in F_4 and F_5 lines of upland cotton. The lines were produced from intervarietal crosses between inbred parents. Each line traced back to a single, randomly chosen, F_2 parent. The variance estimates were taken from an analysis of variance. The between-line variances were considered to be genetic and the plot error variances were environmental. The environmental variances for lint yield, bolls per plant, seed per boll, and boll weight were large relative to their genetic variance. For lint percentage, seed and lint index, and the various fiber measurements the relative estimates of genetic variances were large. They concluded from this study that there was sufficient genetic variability present, in all characters studied, to make progress by selection.

Two methods of estimating genetic variances in a diploid species of cotton, Gossypium arboreum, were compared by Panse (18). The two characters measured were halo-length and ginning percentage. One method used to estimate genetic variability of these two characters was to calculate

regression coefficients of F_3 means on F_2 parental values. He assumed the regression coefficient represented the genetic fraction of the total variability. The environmental portion of the F_2 variance was obtained by difference. The second method used to estimate genetic variability was to subtract the mean variance for the two inbred parents and the F_1 from the variance of the F_2 generation. If all attributes were grown under similar environmental conditions the difference remaining in the F_2 should be genetic. The second method gave a much lower estimate of total genetic variability than did the first. Panse suggested this to be due to the inbred parents not having been homozygous even after ten generations of inbreeding.

On the other side of the controversy, some workers are of the opinion that there is little remaining genetic variability in upland cotton. Richmond (22) is of the opinion that future needs cannot be met by selecting within existing cotton varieties. However, he (21) pointed out the need for improved statistical methods for determining residual variability in cotton. Richmond stated that present day varieties descended from about a dozen original introductions and he doubted if the amount of genetic variability present in upland stocks were sufficient to meet future demands.

Mason (16) maintained secondary selection in cotton was not justified on the basis of results obtained. He thought most of the progress made in cotton had been by primary selection and not by secondary selection.

Hutchinson (11) postulated that natural selection favored a range of types and not a single type. He maintained that genetic variability is found in even the most closely bred pedigree stocks and is found in all unselected populations. He further stated no collection of types can compete with an unselected group of plants. According to him it is much more important to maintain variability within a population than to maintain a collection of types. He pointed out that the Cotton Belt

of the United States lies outside the area of high variability for Gossypium hirsutum L.; therefore, genetic variability will have to be produced by hybridization.

Comstock et al (5, 6) in 1949 and 1955 and Robinson et al (23) in 1955 discussed methods of estimating genetic variability in open-pollinated and segregating generations of corn. Their hybrid populations were produced from lines that had been inbred at least 10 generations. An F_2 population was produced from these lines and "bi-parental" crosses were made within this population. Their procedure was as follows:

A randomly chosen F_2 plant was used to pollinate four F_2 female plants also chosen at random. Individual plant data for eight characters were taken on each parent plant. The F_3 progenies from the F_2 "bi-parental" crosses were grown in replicated tests. The same eight characters were measured in the F_3 progenies as were measured on the F_2 parent plants.

Regression coefficients of F_3 progeny means on F_2 parent plants were calculated. From these data estimates of genetic variances were made. In the second method components of variance were estimated utilizing data from an analysis of variance of the F_3 population. These estimates were used to partition the total variability into its components parts. A third method of estimating genetic variability was reported. Again an analysis of variance was used to estimate the components of variance. It differs from the afore-mentioned method in that no "bi-parental" crosses were made. The F_2 plants were backcrossed to the two inbred parents and the amount of genetic variability was estimated from variance components. They concluded from these experiments that both the hybrid stocks and open-pollinated varieties analyzed had an important amount of genetic variance. Sprague (27) discussed these data and indicated it should be possible to make genetic progress toward increasing yield by selecting within existing open-pollinated varieties of corn.

Woodworth et al (30) were able to demonstrate variability for oil and protein content in corn after 50 generations of selecting. The original population was foundation seed stock of the Burr White variety. They selected four lines. Each line was selected for one of the following characters: low oil, high oil, low protein, and high protein. The selected lines were propagated by ear-to-row selection for the first 28 generations. Mass selection with intra-strain controlled cross-pollination was utilized for the last 22 generations. The original population had an average of 4.70 per cent oil, and 10.92 per cent protein. After 50 generations the line for high oil had 15.36 per cent oil and the low oil line had 1.01 per cent oil. The line for high protein had 19.45 per cent protein and the line for low protein had 4.91 per cent protein. After 47 generations progress by reverse selection could be made in three lines. The coefficient of variation remained almost unchanged in the high oil line. There was an increase in the coefficient of variation in the low oil line. The same statistical measurement indicated an increase in variability for the high protein and corresponding decrease in variability for the low protein line. These data indicate further progress is possible in all but the low oil line.

Powers (19, 20) investigated genetic and environmental variances in fruit weight, locule number and weight, and other characters in tomatoes. He estimated genetic variance in the following manner. He assumed the variance of the two inbred parents and their F_1 hybrid to be environmental. The difference obtained when this estimate of variance was subtracted from a segregating generation's variance was genetic.

He found the size of variance and mean for each generation to be positively correlated. Using these data he was able to predict, rather closely, the individual variances of the F_1, F_2 and reciprocal backcross generations.

Comstock (4) suggested that genetic variances are not static. According to him shifts in gene frequency or linkage may increase or decrease genetic variance; therefore, care should be taken about being too dogmatic about any one set of data.

Studies on Heritability Estimates

There are many published reports on determining heritability estimates. Only one example of each method will be presented. According to Warner (29) these fall into four main categories. He lists three of these methods and suggested a fourth. The three he listed are: "(a) parent-offspring regression, (b) variance components from an analysis of variance, and (c) approximation of nonheritable variance from genetically uniform populations to estimate total genetic variance." The fourth method, the one he suggests, is based entirely on estimates of variance of the F_2 and the reciprocal backcross generations. The formulae for computing the estimates are presented in the Materials and Methods section of this thesis.

Bilbro (1) used Warner's (29) method to estimate the heritability of Micronaire values in upland cotton. His estimates in per cent were 30.35, 73.57, and 60.72. The first and last estimates were for a variety grown under two different environments and the middle estimate was for the combined data of the two environments.

Robinson et al (23) compared two methods of estimating heritability in corn. The data used for these estimates were from the corn population described in the preceding section on residual variability. Heritability estimates for the same eight characters were made. The first method described corresponds to method (a) listed by Warner (29). Parent offspring regressions were run on data obtained from the F_2 and F_3 generations.

The regression "b" was derived from an analysis of covariance. Two times the regression coefficient was the estimate of heritability.

The second method described by Robinson et al (23) corresponds to method (b) listed by Warner (29). Variance components were estimated from an analysis of variance. From these components the additive genetic variance was estimated. The heritability estimate was the ratio of the additive genetic variance to total variance. They concluded from their data that the two methods of estimating heritability agreed very well.

Method (c) described by Warner (29) differs from method (b) only in the method of partitioning genetic variance from total variance. Stith (28) used this method to estimate heritability in cotton.

The mean variance of the P_1, P_2 and F_1 was subtracted from the variance of the F_2. He postulated the remaining variance was genetic. The ratio of genetic variance to total variance was the heritability estimate. The estimates in per cent were: 45.3 for lint percentage, 50.1 for boll size, 22.2 for staple length, 54.1 for fiber strength, and 69.9 for fiber fineness.

MATERIALS AND METHODS

Materials

Four different varieties were used for these studies. Two were inbred lines of the varieties Half and Half and Washington. These inbred lines had been maintained for several generations by bulk self-pollination. In these studies Half and Half and Washington were designated as "inbreds". The other two varieties, Stoneville 62 and CR-2, had been maintained under open-pollinated conditions for several generations. Both varieties were developed in Oklahoma, Stoneville 62 near Stillwater, where natural crossing has been estimated to be 33 per cent, and CR-2 near Tipton with natural crossing about 25 per cent (8, 24).

Heritability Experiments

The two inbred lines were crossed. F_1, F_2 and reciprocal backcross generations were produced from both varietal combinations (Table I). The F_0 seed of CR-2 times Stoneville 62 and Washington times Half and Half was produced at Perkins, Oklahoma in 1954. The two inbred parents and the two F_1 populations were grown in Mexico during the winter of 1954-55. The self-pollinated seed from the F_1 populations and the inbred parents was harvested and stored. The method of crossing is described under "Heterozygosity Experiments".

The two populations of F_1 plants and their parent varieties were grown on the Cotton Research Station near Chickasha, Oklahoma during the

summer of 1955. Reciprocal backcrosses were made and harvested seed was stored.

The two heritability tests were planted in May on the Cotton Research Station and were harvested in November and December of 1956. Each heritability test included the two parents, their F_1, F_2 and reciprocal backcross generations. One test had the inbred lines for parents, the other, open-pollinated varieties (Table I).

Within row variances were computed for all entries. The mean variance was computed on an individual plant basis. Warner's (29) method of estimating heritability was used. He presented the following formulae:

Heritability = $\frac{(\frac{1}{2}D)}{V_{F_2}}$ where $(\frac{1}{2}D)$ = [2(variance of F_2) - (variance of B_1 + variance of B_2)]; B_1 = variance of $(F_1 \times P_1)$; B_2 = variance of $(F_1 \times P_2)$; and V_{F_2} = variance of the F_2.

These estimates and the frequency distributions were used to determine the inheritance of lint per cent, total yield of lint, per cent first harvest, and Micronaire values in these two tests.

The type of gene action involved in the inheritance of these four characters was estimated. The formulae suggested by Bilbro (1) and by Charles and Smith (3) were used for this computation. The formulae used were as follows:

Generation	Expected Means	
	Arithmetic	Geometric
F_1	$\frac{\bar{P}_1 + \bar{P}_2}{2}$	$\sqrt{\bar{P}_1 \cdot \bar{P}_2}$
F_2	$\frac{\bar{P}_1 + 2\bar{F}_1 + \bar{P}_2}{4}$	
$F_1 \times P_1$	$\frac{\bar{P}_1 + \bar{F}_1}{2}$	$\sqrt{\bar{P}_1 \cdot \bar{F}_1}$
$F_1 \times P_2$	$\frac{\bar{P}_2 + \bar{F}_1}{2}$	$\sqrt{\bar{P}_2 \cdot \bar{F}_1}$

TABLE I

SOURCES OF SEED FOR ENTRIES IN TWO HETEROZYGOSITY AND TWO HERITABILITY EXPERIMENTS GROWN IN 1956

Experiment	Entry	Source of Seed
Heritability Experiment using inbreds	Half and Half	Bulked self-pollinated seed
	Washington	Bulked self-pollinated seed
	F_1	Half and Half x Washington
	F_2	(H and H x Wash.) F_1 self-pollinated
	$F_1 \times P_1$	(H and H x Wash.) x H and H
	$F_1 \times P_2$	(H and H x Wash.) x Wash.
Heritability Experiment using varieties	Stoneville 62	Breeders seed
	CR-2	Breeders seed
	F_1	Stoneville 62 x CR-2
	F_2	(Sto. 62 x CR-2) F_1 self-pollinated
	$F_1 \times P_1$	(Sto. 62 x CR-2) x Sto. 62
	$F_1 \times P_2$	(Sto. 62 x CR-2) x CR-2
Heterozygosity in CR-2	CR-2	Breeders seed
	Half and Half	Bulked self-pollinated seed
	CR-2 S_1	Self-pollinated seed from 50 CR-2 plants grown from breeders seed
	F_1	The above 50 CR-2 plants crossed with inbred Half and Half plants

TABLE I (Continued)

Experiment	Entry	Source of Seed
	Stoneville 62	Breeders seed
Heterozygosity in Stoneville 62	Washington	Bulked self-pollinated seed
	Stoneville 62 S_1	Self-pollinated seed from 50 Sto. 62 plants grown from breeders seed
	F_1	The above 50 Sto. 62 plants crossed with inbred Washington plants

Heterozygosity Experiments

Two heterozygosity experiments were conducted in an effort to establish genetic ranges for two open-pollinated varieties of cotton, Stoneville 62 and CR-2. Both varieties were developed in Oklahoma and have been maintained under open-pollinated conditions. Two inbred lines, Washington and Half and Half, were used as tester varieties (Table I). These two testers had been maintained by bulking self-pollinated seed for several generations. The same procedures were used for each test.

In 1954 a plot consisting of 75 plants of each open-pollinated variety and approximately ten plants of each inbred line were grown. The two tester lines were used as pollen parents and each were crossed with plants of one open-pollinated variety. The crosses were made by hand emasculating buds on the open-pollinated parent plants each afternoon and applying pollen from the inbred line the following morning. Drought conditions were so severe that few bolls were set. F_0 seed was harvested from each individual plant and stored.

The four plant populations were cut-back and moved into the greenhouse in October of 1954. Crosses were made, in the greenhouse, in the

same manner as in the field the previous summer, to obtain additional F_0 seed. Unfortunately, in crossing incorrect combinations were made in the greenhouse; consequently all crossed bolls were discarded. However, selfed seed were saved from all plants, by individual plants, and stored for future use.

In the spring of 1955 the plants were again cut-back and placed in the field at Chickasha, Oklahoma. Crosses were made in the afore-mentioned manner. The cross-pollinated bolls were harvested by individual plants and the seed was stored.

The plants were cut-back and moved to the greenhouse in October 1955. This season the open-pollinated plants were the pollen-parents and the inbred lines were the pistillate ones. Since there is no maternal effect in cotton (27) reciprocal crossing should have had no effect on the F_1 generation. The crossed bolls were identified by the open-pollinated parent since the inbred line was assumed to be homozygous. The F_0 and S_1 seed was again harvested by individual plants and saved.

The accumulated F_0 and S_1 seed from any one open-pollinated plant were bulked separately. The entries in each test consisted of F_0 and S_1 seed from each chosen parent, breeders seed of the open-pollinated parent and self-pollinated seed from the inbred line. Each test contained S_1 and F_1 seed from 50 open-pollinated plants plus the inbred parent progeny. Each S_1, F_1, and the inbred constituted a family. This made a total of 102 entries in each test. The decision to use the progeny from fifty open-pollinated parents was based partially on the amount of seed available and partially on data obtained from a pilot study.

The pilot study was run in 1955 to estimate genetic variances and to determine the number of entries necessary for estimating the range of genetic variances in a population. The test was identical to the one

described in the preceeding paragraph except the progenies from only 15 open-pollinated parents were used. This made a total of 33 entries in the test. Individual attribute variances were determined for Micronaire, lint per cent, per cent first harvest, and total weight of lint.

The test involving CR-2 as the open-pollinated parent and Half and Half as the inbred parent was planted May 5, 1956; thinned June 29, 1956; harvested the first time in October and the second time in November of 1956. The second heterozygosity test had Washington as the inbred parent and Stoneville 62 as the open-pollinated parent. This test was planted June 8, 1956; thinned July 3, 1956; harvested in November and December of 1956. A large portion of the bolls were damaged by a severe freeze in early November.

The estimates of within row genetic variances for the individual attributes were determined by subtracting the variance of the inbred line from the total variance for the F_1 and S_1 progenies using a method similar to the one described by Panse (18).

Description of Environment and Field Experiments

The data and observations reported in these studies were made in 1956 at the Cotton Research Station near Chickasha, Oklahoma. The tests were planted on sandy loam soil. There was ample moisture at planting time for seedling emergence. The following amounts of rainfall in inches were recorded: May, 4.23; June, 2.42; July, 2.04; August, 0.55; September, 0.02; October, 4.44. In addition, fifteen inches of water were applied to these tests in five equal applications with a sprinkler irrigation system. The supplemental irrigation applications were made on the basis of visual observation. When the plants began to wilt, irrigation water was applied. General environmental conditions were

considered good.

All four tests were grown in a randomized complete block design, as described by Snedecor (26). There were 102 entires in each of the heterozygosity experiments and six in each of the heritability experiments. All treatments were replicated 10 times. The entries were planted in one row plots 25 feet long with a 3 foot alley between plots. The plants were spaced 18 inches apart within the row; the rows were spaced 40 inches apart.

The plots were planted with a non-commercial type plot planter designed by the Agricultural Engineering Department, Oklahoma State University. The planter was adjusted to place two seeds 18 inches apart within the row.

The plants were thinned to one per hill when they were about 12 inches high. Weeds were kept down with a hoe and tractor-drawn cultivator. Insect populations were kept at a minimum with various types of commercial insecticides.

The plots were harvested by individual plants in all four experiments. The first and last plant from each plot was discarded to eliminate border effects. The picked cotton was placed in a paper bag with the plant, plot, replication, and experiment numbers written on it.

Data Collected and Statistical Analyses

The following individual plant measurements were recorded for all four experiments: weight of first harvest seed cotton, total weight of seed cotton, total weight of lint and total weight of seed. The weight of seed cotton from the first harvest was recorded by individual plants. The cotton from the first harvest was then combined with the cotton from the second harvest by plants and the total weight of seed cotton from each plant was recorded. The seed cotton was then ginned, the weight of the

lint and seed was recorded and the lint was sent to the fiber laboratory for Micronaire measurements.

The raw data were submitted to the Oklahoma State University statistical laboratory. Individual attribute, within row variances was determined by an analysis of variance. These analyses were computed by an I.B.M. 650 computer. The individual entry data for Micronaire readings, seed cotton weight for first and second harvest, and total weight of lint were direct observations and were punched on computing cards. The individual lint per cent values were obtained by dividing the total weight of lint by the total weight of seed cotton. The per cent first harvest was computed by dividing the weight of seed cotton from the first harvest by the total weight of seed cotton from all harvests. These computations were also by the I.B.M. 650 computor.

Fiber Coarseness Measurements

The Micronaire[1/] was used to determine the coarseness of all lint samples. Fifty grains of clean hand-fluffed cotton are required for each reading. The sample is placed in a cylinder and compressed to a predetermined volume. Compressed air flowing through the lint sample causes a small float to rise in a scaled transparent tube and the readings are taken directly. The readings are expressed as micrograms per inch of fiber. Two such samples were run from each lot of cotton and an average of the two readings was recorded as the sample's value.

1/ A description of this instrument may be found in Cotton Production, Marketing and Utilization. Published by W. B. Andrews, State College, Mississippi. p. 299. 1950.

RESULTS

Inheritance of Characters Studied

In order to aid in interpreting the results of the investigation of residual heterozygosity in CR-2 and Stoneville 62, it was thought desirable to study the heritability of characters measured under the conditions existing when the tests were grown. Two independent estimates of heritability were made, one using the two varieties and the other using the inbred lines, Washington and Half and Half. Since all characters measured were considered to be inherited quantitatively, genetic analysis was limited to determining whether mean values of F_1, F_2 and backcross populations indicated arithmetic or geometric gene action.

(1) Micronaire values

The heritability estimate for Micronaire (fiber coarseness or fineness) calculated from the cross of Half and Half x Washington was low. This was due to the high variability of the backcross generation having Half and Half as the recurrent parent. The variance of this backcross generation approximated that of the F_2 generation (Table II). The numerical estimate of heritability from this cross was 2.29 per cent.

The heritability estimate calculated from the cross of Stoneville 62 x CR-2 was 64.00 per cent. These two open-pollinated parents produced an F_2 generation having a larger variance than either backcross generation (Table III). The estimates of expected means in both experiments were

TABLE II

MEAN SQUARES AND MEAN MICRONAIRE VALUES OF WASHINGTON, HALF AND HALF AND FOUR POPULATIONS DERIVED FROM A CROSS BETWEEN THEM, COMPARED WITH EXPECTED VALUES ASSUMING ARITHMETIC AND GEOMETRIC GENE ACTION

Type of Populations	Number of Individuals	Mean Squares	Observed Mean	Expected Mean	
				Arithmetic	Geometric
Half and Half	35	0.2823	5.14 ± .090	--	--
Washington	75	0.0819	3.53 ± .033	--	--
F_1	45	0.2030	4.26 ± .067	4.34	4.26
F_2	64	0.3235	4.37 ± .071	4.30	--
F_1 x H and H	39	0.3155	4.47 ± .075	4.70	4.68
F_1 x Washington	70	0.2573	4.79 ± .061	3.90	3.88

TABLE III

MEAN SQUARES AND MEAN MICROANIRE VALUES OF STONEVILLE 62, CR-2 AND FOUR POPULATIONS DERIVED FROM A CROSS BETWEEN THEM, COMPARED WITH EXPECTED VALUES ASSUMING ARITHMETIC AND GEOMETRIC GENE ACTION

Type of Population	Number of Individuals	Mean Squares	Observed Mean	Expected Mean	
				Arithmetic	Geometric
Stoneville 62	111	0.2702	3.91 ± .050	--	--
CR-2	101	0.3009	4.57 ± .055	--	--
F_1	87	0.2137	3.95 ± .049	4.24	4.23
F_2	110	0.2735	4.04 ± .050	4.10	--
F_1 x Sto. 62	72	0.2411	3.68 ± .058	3.93	3.93
F_1 x CR-2	55	0.1308	3.33 ± .048	4.26	4.25

similar for both arithmetic and geometric gene action. The calculated means for both experiments approximated the observed means for the F_1 x Washington backcross generation and the F_1 x CR-2 backcross generation. An "F" test indicated the two inbred parent varieties differed at the one per cent level of probability and that the two open-pollinated parent varieties did not differ at the five per cent level of probability. Their not differing would indicate this test of gene action is of questionable value.

(2) Lint per cent

The estimate of heritability for lint per cent obtained from the cross of two inbred varieties, Washington and Half and Half, is of doubtful value. The estimate calculated from data presented in Table IV is 129 per cent. The variance of the F_2 generation was larger than the sum of the variances of the two backcross generations. The large F_2 variance was responsible for the unrealistic estimate of heritability.

The variance estimates obtained from the cross of Stoneville 62 x CR-2 are listed in Table V. These data provided a heritability estimate of .82 per cent. The variance of the F_2 generation was smallest of the group and the backcross generation having CR-2 as the recurrent parent was largest.

The estimates of arithmetic and geometric means were practically the same, within each experiment, as shown in Table V. The calculated means approximated the observed mean, except for one of the backcross generations in each experiment. An "F" test indicated the parent varieties did not differ at the five per cent level of probability within either experiment. Again the test of gene action is of questionable value.

TABLE IV

MEAN SQUARES AND MEAN LINT PER CENT OF HALF AND HALF, WASHINGTON AND FOUR POPULATIONS DERIVED FROM A CROSS BETWEEN THEM, COMPARED WITH EXPECTED VALUES ASSUMING ARITHMETIC AND GEOMETRIC GENE ACTION

Type of Population	Number of Individuals	Mean Squares	Observed Mean	Expected Mean	
				Arithmetic	Geometric
Half and Half	35	2.7750	34.7 ± .28	--	--
Washington	75	2.0972	30.8 ± .17	--	--
F_1	45	4.0873	34.8 ± .30	32.8	32.7
F_2	64	8.8592	35.1 ± .37	33.8	--
F_1 x H and H	39	2.8047	35.2 ± .22	34.8	34.7
F_1 x Washington	70	3.5110	36.6 ± .22	32.8	32.7

TABLE V

MEAN SQUARES AND MEAN LINT PER CENT OF STONEVILLE 62, CR-2, AND FOUR POPULATIONS DERIVED FROM A CROSS BETWEEN THEM, COMPARED WITH EXPECTED VALUES ASSUMING ARITHMETIC AND GEOMETRIC GENE ACTION

Type of Population	Number of Individuals	Mean Squares	Observed Mean	Expected Mean	
				Arithmetic	Geometric
Stoneville 62	111	3.6788	35.4 ± .18	--	--
CR-2	101	3.0569	38.5 ± .18	--	--
F_1	87	3.1191	36.9 ± .19	37.0	36.9
F_2	110	2.6789	36.4 ± .16	36.9	--
F_1 x Sto. 62	72	2.7774	35.8 ± .20	36.2	36.1
F_1 x CR-2	55	4.7904	32.4 ± .30	37.7	37.7

(3) Per cent first harvest

The Half and Half x Washington variances for per cent first harvest are presented in Table VI. The large variances of the Half and Half parent and the backcross generation having Half and Half as a recurrent parent make the estimate of heritability of doubtful value. These large variance estimates produced an unrealistic heritability estimate of -5.7 per cent.

The data presented in Table VII indicated the variances of the populations derived from a cross of Stoneville 62 x CR-2 followed the expected pattern. The F_2 population had the largest variance and the backcross generations were somewhat intermediate between the F_2 population variance and the variance of their respective parent. These data produced a heritability estimate of 47.6 per cent.

Again the test for type of gene action was disappointing for both the inbred and open-pollinated experiments. All calculated means approximated the observed means. However, the parent varieties did not differ, within either population, at the five per cent level of probability, as compared by an "F" test.

(4) Yield of lint

The variance of the F_2 generation was smaller than the variance of either backcross generation in the experiment involving the cross of the inbred varieties Washington and Half and Half (Table VIII). It was axiomatic that such data should lead to a negative estimate of heritability. The estimate was -39.77.

A similar situation was observed in the population resulting from a cross of Stoneville 62 x CR-2 (Table IX). These data indicated a lower

TABLE VI

MEAN SQUARES AND MEAN PER CENT FIRST HARVEST OF HALF AND HALF, WASHINGTON AND FOUR POPULATIONS DERIVED FROM A CROSS BETWEEN THEM, COMPARED WITH EXPECTED VALUES ASSUMING ARITHMETIC AND GEOMETRIC GENE ACTION

Type of Population	Number of Individuals	Mean Squares	Observed Mean	Expected Mean	
				Arithmetic	Geometric
Half and Half	35	343.61	83.6 ± 3.14	--	--
Washington	75	284.08	69.8 ± 1.94	--	--
F_1	45	244.17	82.2 ± 2.33	76.7	76.4
F_2	64	334.89	79.5 ± 2.29	79.5	--
F_1 x H and H	39	451.86	77.8 ± 2.83	82.9	82.9
F_1 x Washington	70	236.90	84.9 ± 1.83	76.0	75.7

TABLE VII

MEAN SQUARES AND MEAN PER CENT FIRST HARVEST OF STONEVILLE 62, CR-2 AND FOUR POPULATIONS DERIVED FROM A CROSS BETWEEN THEM, COMPARED WITH EXPECTED VALUES ASSUMING ARITHMETIC AND GEOMETRIC GENE ACTION

Type of Population	Number of Individuals	Mean Squares	Observed Mean	Expected Mean	
				Arithmetic	Geometric
Stoneville 62	111	454.95	78.6 ± 2.03	--	--
CR-2	101	480.82	65.7 ± 2.19	--	--
F_1	87	458.56	74.0 ± 2.30	72.2	71.9
F_2	110	685.75	69.8 ± 2.49	73.1	--
F_1 x Sto. 62	72	553.82	71.7 ± 2.77	76.3	76.3
F_1 x CR-2	55	491.53	72.3 ± 3.00	69.9	69.7

TABLE VIII

MEAN SQUARES AND MEAN YIELD OF LINT IN GRAMS OF HALF AND HALF, WASHINGTON, AND FOUR POPULATIONS DERIVED FROM A CROSS BETWEEN THEM, COMPARED WITH EXPECTED VALUES ASSUMING ARITHMETIC AND GEOMETRIC GENE ACTION

Type of Population	Number of Individuals	Mean Squares	Observed Mean	Expected Mean	
				Arithmetic	Geometric
Half and Half	35	276.55	271 ± 2.82	--	--
Washington	75	105.96	265 ± 1.18	--	--
F_1	45	328.35	368 ± 2.70	268	268
F_2	64	270.48	331 ± 2.06	318	--
F_1 x H and H	39	317.22	347 ± 2.37	320	311
F_1 x Washington	70	331.33	352 ± 2.17	317	308

TABLE IX

MEAN SQUARES AND MEAN YIELD IN GRAMS OF STONEVILLE 62, CR-2, AND FOUR POPULATIONS DERIVED FROM A CROSS BETWEEN THEM, COMPARED WITH EXPECTED VALUES ASSUMING ARITHMETIC AND GEOMETRIC GENE ACTION

Type of Population	Number of Individuals	Mean Squares	Observed Mean	Expected Mean	
				Arithmetic	Geometric
Stoneville 62	111	74.55	309 ± .82	--	--
CR-2	101	95.59	280 ± .98	--	--
F_1	87	210.22	350 ± 1.56	295	294
F_2	110	109.70	280 ± 1.00	322	--
F_1 x Sto. 62	72	119.59	314 ± 1.29	330	329
F_1 x CR-2	55	132.37	298 ± 1.56	315	313

variance for the F_2 population than for either of the backcross generations. These erratic data produced a heritability estimate of -29.68 per cent.

In the test for type of gene action affecting yield of lint, only the means calculated for the F_2 generation of the Half and Half x Washington cross were within one standard deviation of the observed mean (Table VIII). The arithmetic and geometric calculated means had approximately the same values. An "F" test indicated the two inbred parents differed at the one per cent level of probability.

Data from the cross of Stoneville 62 x CR-2 indicated a pattern, for the type of gene action governing yield, similar to that described for the two inbred varieties. The calculated arithmetic and geometric mean were similar. However, neither group approached the observed means. An "F" test indicated these two parent varieties did not differ at the five per cent level of probability.

Heterozygosity of Characters Studied

The individual plant within-row variances from the Stoneville 62 x Washington heterozygosity experiments are presented in the appendix tables. The hypothesis followed in interpreting these data was that the variance of the S_1 progeny should exceed that of the F_1 and both should exceed that of the inbred progeny within the same family.

The data in Table X indicated that the Half and Half supposedly inbred parent was not homozygous for the four characters being studied. Therefore, the experiment having Half and Half as the inbred parent and CR-2 as the open-pollinated parent was not presented in the results section. However, tables containing these data were placed in the appendix.

TABLE X

VARIANCE ESTIMATES FROM A HERITABILITY EXPERIMENT INVOLVING TWO INBRED VARIETIES AND A HERITABILITY EXPERIMENT INVOLVING TWO OPEN-POLLINATED VARIETIES

	Mean Square Values From an Analysis of Variance			
Character	Inbr. H. & H.	Inbr. Wash.	O.P. Sto.62	O.P. CR-2
Micronaire	.2823	.0819	.2702	.3009
Lint per cent	2.775	2.097	3.679	3.057
Per cent 1st. harvest	343.61	284.08	454.95	480.82
Yield of lint	276.55	105.96	74.55	95.59

(1) Micronaire values

Heterozygosity in 31 families for Micronaire (fiber coarseness or fineness) was indicated since the expected $\sigma^2_{S_1} > \sigma^2_{F_1} > \sigma^2$ inbred (Table XI). In the remaining 19 families $\sigma^2_{S_1} > \sigma^2$ inbred which indicated heterozygosity in the parent plants of the S_1 progenies. However, the $\sigma^2_{F_1}$ did not fit the expected in these 19 families.

Data presented in Table XII show the inbred parent had the lowest grand mean variance. The S_1 population grand mean variance was larger than that of the F_1 population, according to expectation. The variance of the population propagated directly from Stoneville 62 breeder's seed was larger than that of the S_1 population. In an effort to determine if the sample size of the families were adequate, those families having 60 or more plants in both the S_1 and F_1 progenies were compared in Table XIII. Eliminating the families with few plants did not effect the grand mean

TABLE XI

RANK OF VARIANCES OF INBRED WASHINGTON, S_1 PROGENIES OF STONEVILLE 62 PLANTS, AND F_1 HYBRIDS OF STONEVILLE 62 PLANTS x INBRED WASHINGTON

Rank of Variances	Micronaire	Lint Per cent	Per cent first harvest	Yield of lint
$S_1 > F_1 >$ Inbr.	31	11	4	16
$F_1 > S_1 >$ Inbr.	18	9	9	27
$S_1 >$ Inbr. $> F_1$	1	7	11	1
$F_1 >$ Inbr. $> S_1$	--	8	16	5
Inbr. $> S_1 > F_1$	--	7	6	--
Inbr. $> F_1 > S_1$	--	8	4	1

TABLE XII

MEAN VARIANCES OF PROGENIES OF 50 STONEVILLE 62 PLANTS, CROSSES OF EACH OF THE 50 PLANTS WITH INBRED WASHINGTON, AND VARIANCES OF INBRED WASHINGTON AND THE STONEVILLE 62 VARIETY FOR THE INDICATED CHARACTERS

	Mean Square Values From an Analysis of Variance			
Character	O.P. Sto. 62 S_1	(Sto. 62 x Wash.) F_1	Inbr. Wash.	O.P. Sto. 62 Breeders Seed
Micronaire	.1097	.0845	.0392	.1508
Lint per cent	4.329	4.149	3.803	4.157
Per cent 1st. harvest	316.4	352.1	320.9	332.9
Yield of lint	283.3	332.9	201.6	315.8

TABLE XIII

MEAN VARIANCES OF SELECTED FAMILIES[1/] [2/] OF STONEVILLE 62 PLANTS AND THEIR CROSSES WITH INBRED WASHINGTON COMPARED WITH THE VARIANCES OF INBRED WASHINGTON

Character	Mean Square Values From an Analysis of Variance		
	O.P. Sto. 62 S_1	(Sto. 62 x Wash.) F_1	Inbr. Wash.
Micronaire[1/]	.1038	.0786	.0392
Lint per cent[1/]	4.703	3.817	3.803
Per cent 1st. harvest[2/]	326.6	333.2	320.9
Yield of lint[2/]	246.14	320.11	201.60

[1/] Data from families having 60 or more plants in the F_1 and S_1 generation.

[2/] Data from families having 55 or more plants in the F_1 and S_1 generation.

variance appreciably. In this comparison the grand mean variance of the S_1 and F_1 progenies went up slightly. However, there was no change in over-all rank.

The arrays of total variance in F_1 and S_1 for Micronaire values are presented in Figure 2. The genetic variances for the same values are arrayed in Figure 1. The range of genetic variance was from .01 to .22 compared with a total variance range of .04 to .26.

(2) Lint per cent

Data presented in Table XI indicated 11 of the 50 families examined for residual heterozygosity fit the expected. In these families the $\sigma^2_{S_1} > \sigma^2_{F_1} > \sigma^2$ inbred. Sixteen other families showed the following pattern of variances: $\sigma^2_{S_1} > \sigma^2$ inbred. These sixteen families were slightly suspect

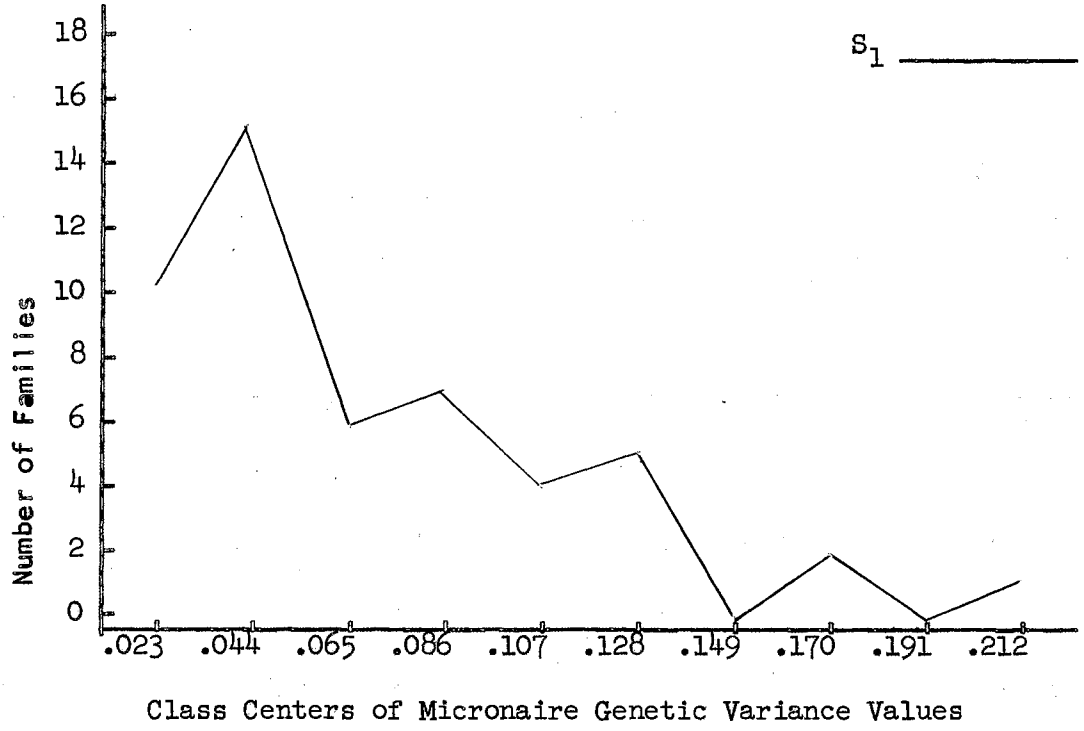

Fig. 1 Frequency distribution of genetic variance present for Micronaire in 50 Stoneville 62 progenies.

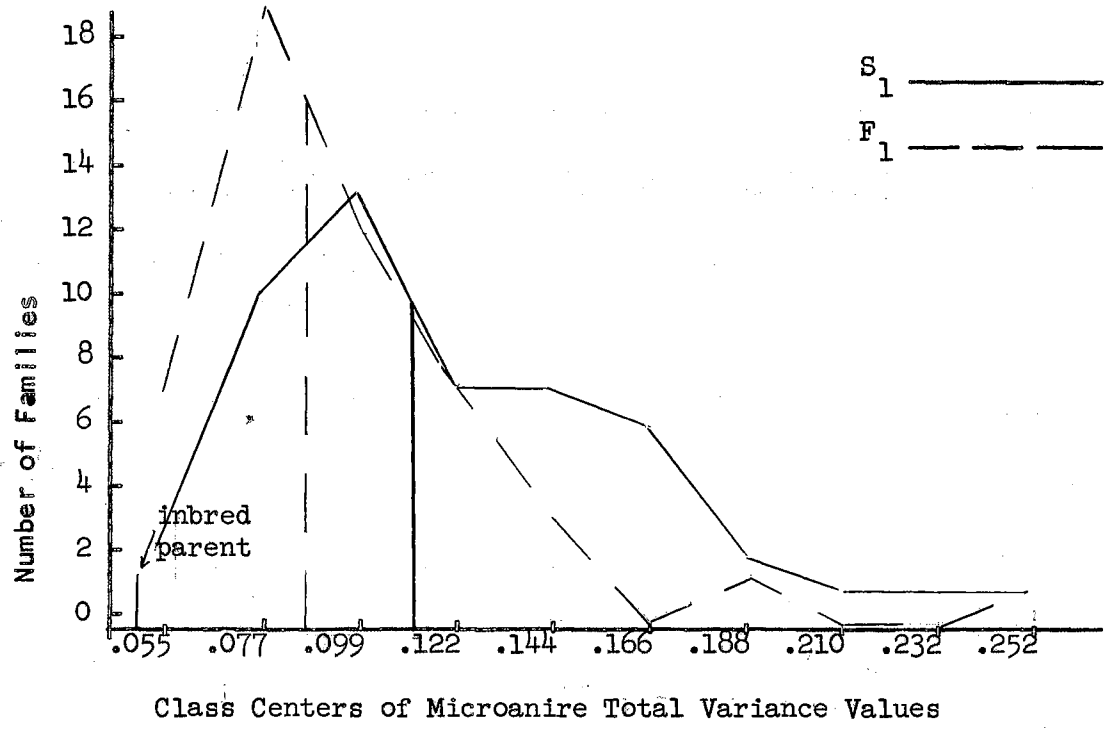

Fig. 2 Frequency distributions of variances of Micronaire readings on S_1 progenies of 50 Stoneville 62 plants and on the F_1's of their crosses with inbred Washington.

in that the F_1 did not follow the model suggested by the original hypothesis. However, the S_1 plant variances indicated heterozygosity in the parent, Stoneville 62, variety. The remaining 23 family variances were erratic.

The grand mean variances for the fifty families followed the expected pattern in that the $\sigma^2_{S_1} > \sigma^2_{F_1} > \sigma^2$ inbred. Families with 60 or more plants in both the S_1 and F_1 progenies were included in Table XIII and the S_1, F_1 and inbred progeny variances were compared. The grand mean variances of these families indicated the S_1 progeny variance went up and the F_1 progeny variance went down in numerical value, when compared to the grand mean variances of all the families. However, there was no change in overall rank of the variances. On the basis of these data it is regrettable there were not more plants in some families.

The variances of the S_1 progenies and F_1 hybrids with inbred Washington from the 50 Stoneville 62 parent plants are arrayed in Figure 4. Figure 3 contains the arrayed genetic variances of the S_1 plants having a total variance larger than the Washington inbred parent. The range of estimated genetic variance was from .002 to 5.130. The range of total S_1 variances for the fifty plants was from 1.649 to 8.933.

(3) Per cent first harvest values

The estimate of residual heterozygosity for per cent first harvest (earliness) in the 50 Stoneville 62 parent plants was erratic. Only four of the fifty plants produced families with the expected rank of $\sigma^2_{S_1} > \sigma^2_{F_1} > \sigma^2$ inbred. Nine other plants produced families with $\sigma^2_{F_1} > \sigma^2_{S_1} > \sigma^2$ inbred which fits the original hypothesis. However, the F_1 variance did not fit the expected. The grand mean of the S_1 progeny variances and

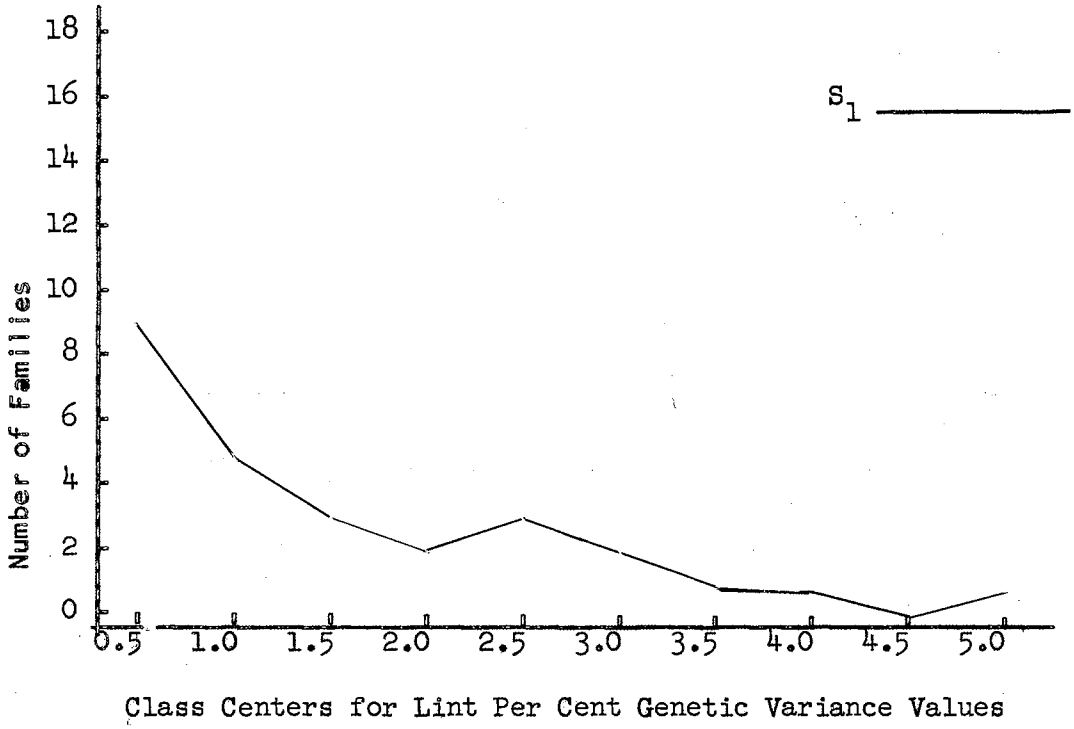

Fig. 3 Frequency distribution of genetic variance present for lint per cent in 50 Stoneville 62 S_1 progenies.

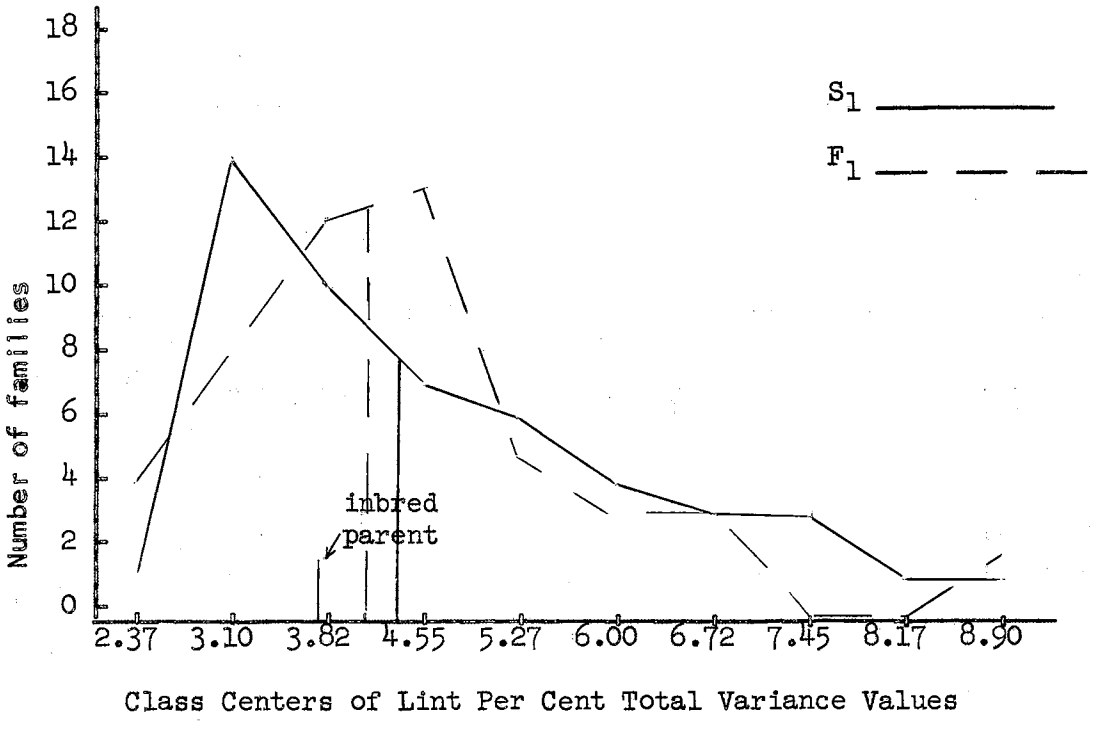

Fig. 4 Frequency distributions of variances of lint per cent values on S_1 progenies of 50 Stoneville 62 plants and on the F_1 of their crosses with inbred Washington.

the mean of the inbred progeny variance were similar. Their values were 316.4 and 320.9 respectively. The grand mean for the F_1 progeny variances was 352.0 which was considerably higher than that of either parent. The mean variance of the Stoneville 62 progeny propagated from breeder's seed was 332.88 which was similar to the estimates for the two parental populations (Table XII).

The families with both the S_1 and F_1 progenies having 55 plants or more were compared. These families produced a more realistic group of variances than did the original population. However, the estimates comparing the grand means still did not fit the expected model (Table XIII). The mean variance of the F_1 was still larger than that of either parent.

The arrayed S_1 and F_1 progeny variances in Figure 6 and the arrayed S_1 genetic variances in Figure 5 indicated considerable variance for this character in the population being investigated. The mean per cent first harvest values for the 50 S_1 plants were arrayed in Figure 9. Their range was from 52 per cent to 80 per cent. The F_1 progeny means were also arrayed in the same figure in an effort to determine if heterosis for yield existed in this population. These data indicated no heterotic effect for per cent first harvest existed in this population. Further, a grand mean of 70.31 per cent first harvest for the S_1 progenies, 59.17 for the inbred progeny, and 65.57 for the F_1 progenies indicated little or no heterotic effect for this character.

The early freeze that destroyed late bolls was undoubtedly an important factor in disturbing results obtained with this character.

(4) Yield of lint

Data presented in Table XI indicated sixteen of the Stoneville 62 families had the expected variance rankings of $\sigma_{S_1} > \sigma^2_{F_1} > \sigma^2$ inbred.

Fig. 5 Frequency distribution of genetic variance for per cent first harvest in 50 Stoneville 62 S_1 progenies.

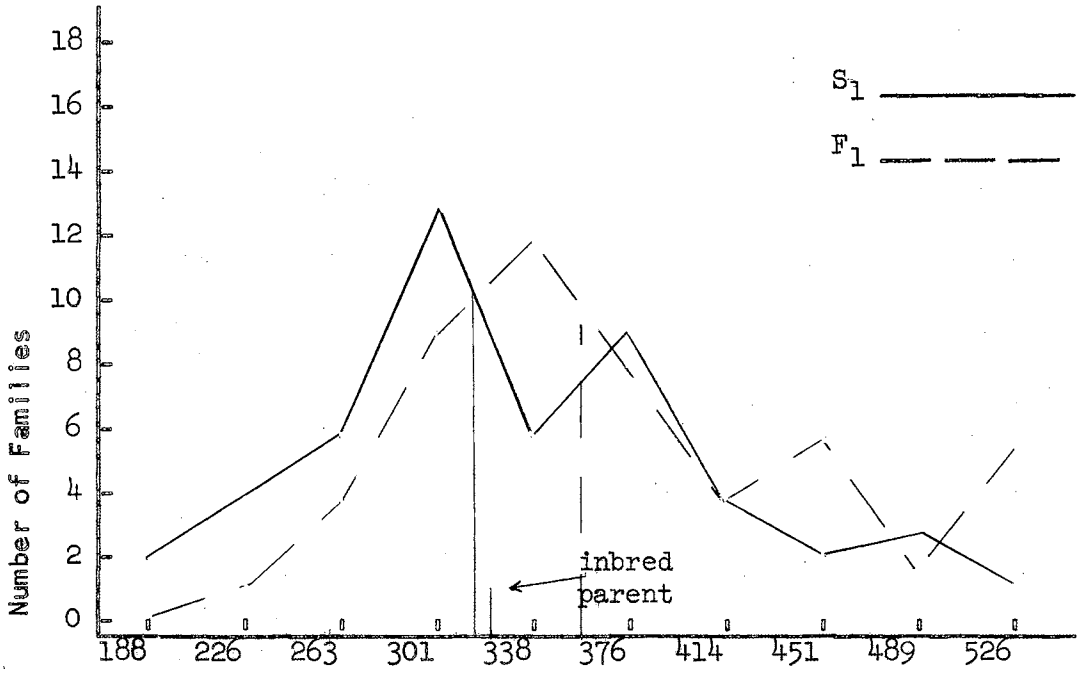

Fig. 6 Frequency distributions of variances of per cent first harvest values on S_1 progenies of 50 Stoneville 62 plants and on the F_1's of their crosses with inbred Washington.

Twenty-eight additional families had $\sigma^2_{S_1} > \sigma^2$ inbred. These twenty-eight families did not fit the expected because the F_1 variance exceeded the variance of the two parents. In the remaining six families there was no evidence of heterozygosity.

The rank of the grand means for the three populations was similar to the rankings under "per cent first harvest". The order was $\sigma^2_{F_1} > \sigma^2_{S_1} > \sigma^2$ inbred. The comparison of families with 55 or more plants in both the S_1 and F_1 generation did not bring the variance estimates closer to the expected. The grand means for the F_1 and S_1 families retained their original ranking relative to each-other and to the inbred. The mean variance of the S_1 decreased from 283.3 to 246.14 and the variance of the F_1 decreased from 332.9 to 320.11. This limited comparison was further from the expected than was the comparison including all families (Table XIII).

The arrayed S_1 and F_1 variances in Figure 8 and the arrayed genetic variances of the S_1 in Figure 7 indicated considerable heterozygosity for yield of lint in the original 50 Stoneville 62 plants. Further evidence of the residual variability present for yield of lint was suggested by the arrayed S_1 and F_1 means. The mean yield of lint for the fifty S_1 progenies and the 50 F_1 progenies are presented in Figure 10. The grand mean of the S_1 and inbred compared with the grand mean of the F_1 progenies indicated there was a heterotic effect for yield of lint in the F_1 generation. The per plant grand mean yield of lint for the S_1 was 38.26 grams, 35.13 grams for the inbred, and 41.35 grams for the F_1. The F_1 yielded an average of 11.13 per cent more than the midparent, 7.23 per cent more than the high parent, and 15.05 per cent more than the low parent.

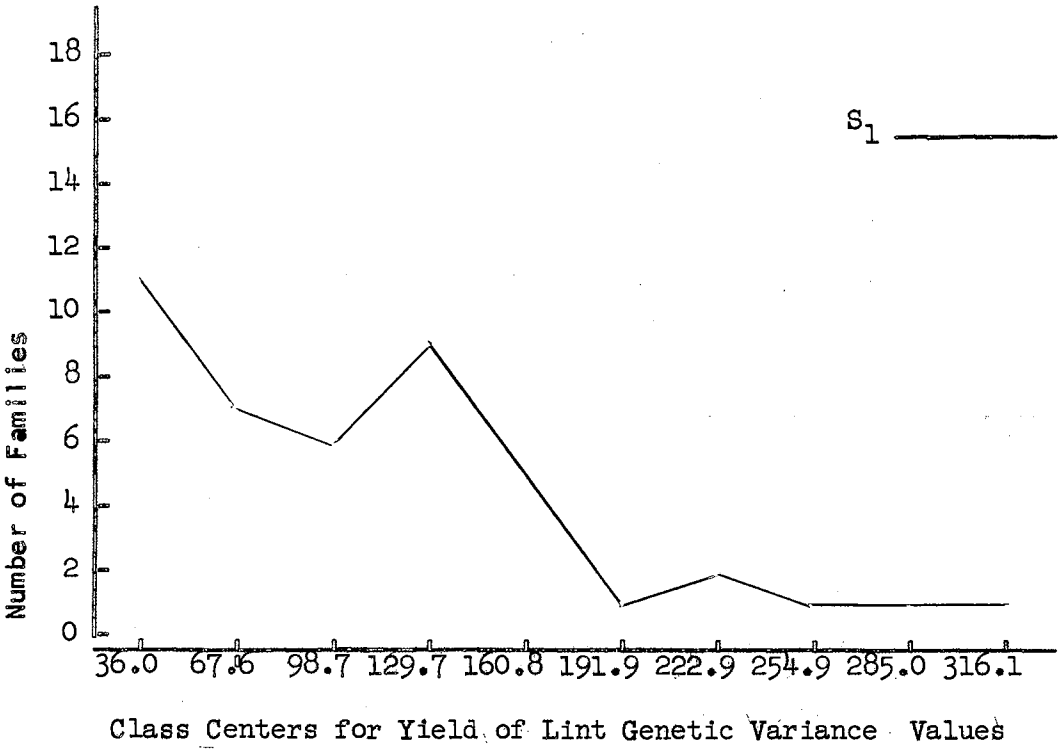

Fig. 7 Frequency distirbution of genetic variance for yield of lint in 50 Stoneville 62 S_1 progenies.

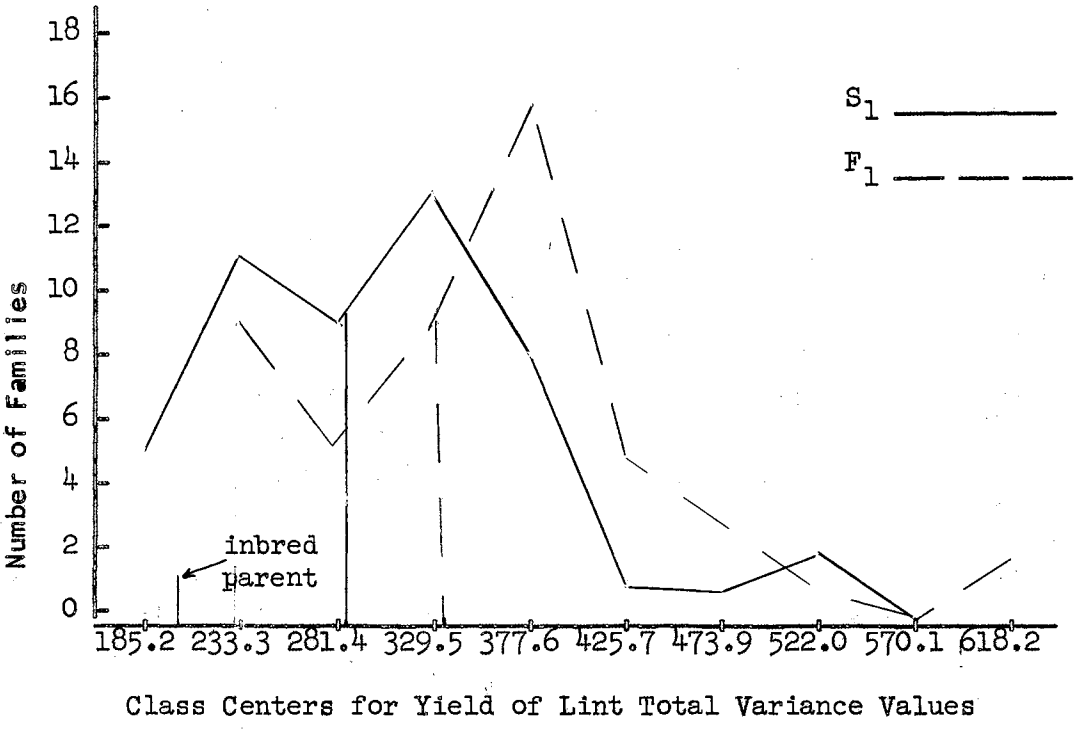

Fig. 8 Frequency distributions of variances of yield of lint values on S_1 progenies of 50 Stoneville 62 plants and on the F_1's of their crosses with inbred Washington.

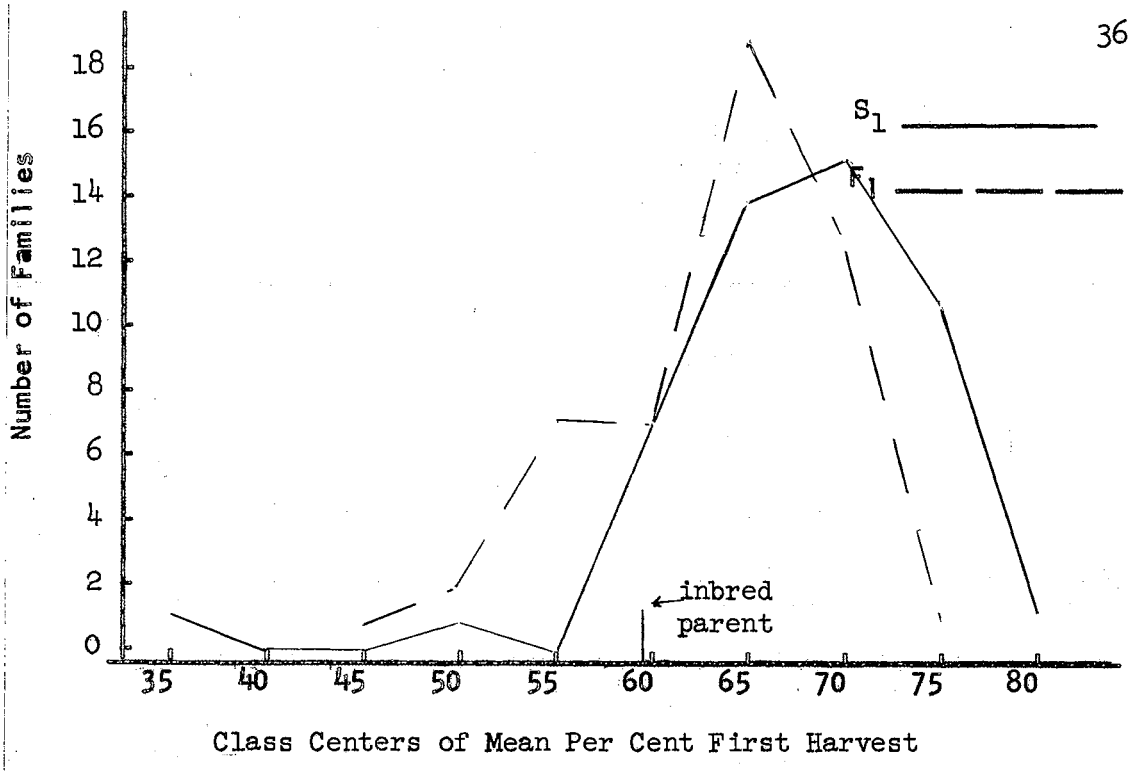

Fig. 9 Frequency distributions of mean per cent first harvest on S_1 progenies of 50 Stoneville 62 plants and on the F_1's of their crosses with inbred Washington.

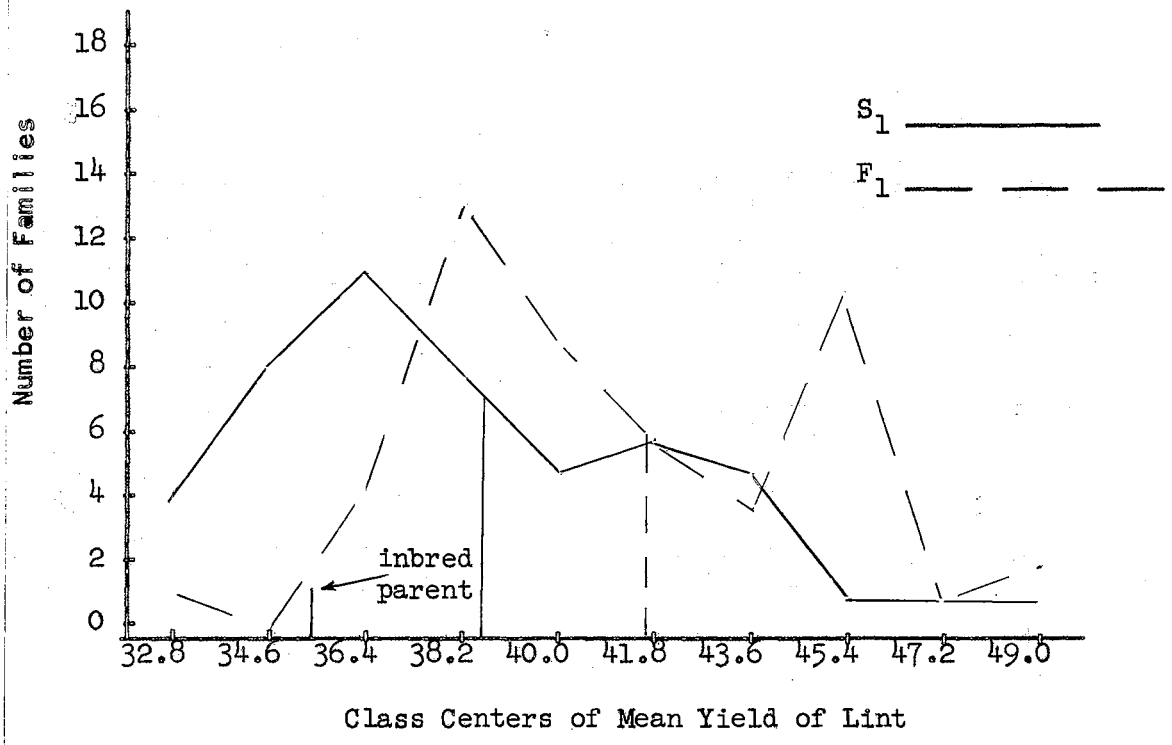

Fig. 10 Frequency distributions of mean yield of lint on S_1 progenies of 50 Stoneville 62 plants and on the F_1's of their crosses with inbred Washington.

DISCUSSION

The estimates of heritability for the experiment involving the two inbred lines may be considered invalid. The estimates are unrealistic in that two have negative values, one estimate is over 100 per cent and one is close to zero. As was previously pointed out in "Results," page 25, the high varibility of the Half and Half parent and the backcross generation having Half and Half as the recurrent parent was partially responsible for the dubious estimates of heritability. Using Warner's (29) method of estimating heritability, one parent having a low variance while the other had a very high variance relative to the F_2 variance would lead to a low estimate but not a negative one.

There are three possible explanations for these estimates not fitting the expected, first being that the size of the Half and Half and F_1 x Half and Half populations was not large enough and the erratic estimates were due to sampling error. The number of plants (observations) in these two populations was less than for any other entry. The second is that a freeze severly damaged these populations before they were mature. This environmental influence could have easily obscured the genetic effects. A third possibility is that the environmental influence was much greater for a genetically uniform population than for a heterozygous one. This explanation would not be satisfactory for the erratic backcross population.

The results of the pilot study conducted in 1955 also indicated the Half and Half inbred parent was heterozygous or that the number of families

was not large enough to overcome sampling errors. At that time, the latter was assumed to be correct, but with the data now available, it appears that the extreme variability of the supposedly inbred Half and Half was very likely the most important disturbing factor.

The test for residual heterozygosity for Microanire value indicated considerable variance for this character in Stoneville 62. Subtracting the variance of the inbred from the average variance of the 50 Stoneville 62 progenies indicated an average genetic variance of .0705. This estimate compared to the grand mean variance value of .1097 for the Stoneville 62 S_1 progenies indicated more than half of the total variance was genetic. The heritability estimate of 64 per cent would indicate most of the genetic variance was additive, according to Lush (13). The skewed distribution of the arrayed total and average genetic variances for the 50 S_1 families indicated several families contained some heterozygosity and a few families were highly heterozygous for fiber coarseness. These distributions lend further support to the assumption that fiber coarseness is quantitatively inherited.

Since the two parent varieties used in the heterozygosity experiment were not grown in the same heritability experiment, their variances cannot be compared statistically. However, it is of interest to note the high variance of the Stoneville 62 variety in one heritability experiment in comparison with the relatively low variance of the F_1 of the Washington inbred in the other heritability experiment. This would lend evidence as to the validity of this method of estimating genetic variance. Further, the estimate of genetic variability was .0453 (expected = .0353) in the F_1 Stoneville 62 x Washington.

In the 31 families fitting the expected model, it is assumed the Stoneville 62 parent plants were heterozygous for fiber coarseness,

the Washington parent was homozygous or nearly so, and the F_1 was intermediate for these factors. In the 18 families having $\sigma^2_{F_1} > \sigma^2_{S_1} > \sigma^2$ inbred the high variability of the F_1 was assumed to be the result of sampling error. However, comparing families with more than 60 plants per F_1 and S_1 progeny did not change the grand mean of the variances much. In the one family having $\sigma^2_{S_1} > \sigma^2$ inbred $> \sigma^2_{F_1}$ the two parents producing the F_1 may have had many homologous genes for fiber coarseness and produced a nearly homozygous population.

The over-all mean variances indicated the Stoneville 62 parent was more heterozygous for factors governing lint per cent than the F_1 and inbred progenies were. Eleven of the 50 Stoneville 62 family progenies had $\sigma^2_{S_1} > \sigma^2_{F_1} > \sigma^2$ inbred which fits the original hypothesis. Seven families had $\sigma^2_{S_1} > \sigma^2$ inbred $> \sigma^2_{F_1}$ which indicates the parent plants were homozygous for the same factors. Nine families had $\sigma^2_{F_1} > \sigma^2_{S_1} > \sigma^2$ inbred, eight had $\sigma^2_{F_1} > \sigma^2$ inbred $> \sigma^2_{S_1}$, seven had σ^2 inbred $> \sigma^2_{S_1} > \sigma^2_{F_1}$ and eight had σ^2 inbred $> \sigma^2_{F_1} > \sigma^2_{S_1}$; none of which fit the original assumption. Since the variances showed a tendency to fit the original hypothesis more closely when the families with few plants were eliminated, the erratic variances are probably the result of sampling error. For a study of this character a much larger population of plants within each family is needed.

The estimate of average genetic variance in the 50 Stoneville 62 plants was obtained by difference. The estimate was .526 compared to a total variance of 4.329. The genetic variance was not reduced by quite one-half in the F_1 generation. The numerical estimate for the F_1 population was .346 instead of the expected .263. The heritability estimate of eight per cent for lint per cent is much lower than the ones reported by Stith (27).

The frequency distributions for total and genetic variances further indicated the extent of heterozygosity in the Stoneville 62 progenies was

extensive. These distributions indicated the factors governing lint per cent were heterozygous in a larger portion of the population than were the factors governing fiber coarseness. Still, the model group for genetic variances was the lowest class center for lint per cent.

The estimates of genetic variances for per cent first harvest were such that no genetic explanation seemed plausible. The over-all variance estimates did not fit the expected model and only four of the 50 families had variances that fit the expected. The plants being frozen before they were mature may have been the reason the genetic effects were obscured. The mean over-all variance estimates for Stoneville 62 and Washington varieties having practically the same numerical value while the F_1 had a much larger estimate would indicate an environmental influence.

The test for residual heterozygosity of yield indicated considerable variance for this character in Stoneville 62. Subtracting the variance of the inbred progeny from the average variance of the 50 open-pollinated plants indicated an average genetic variance of 81.7. The estimate of genetic variance from the families having 55 or more plants in both the S_1 and F_1 progenies was 44.54, thus indicating the populations were adequate for estimating this character. These estimates are considerably higher than those obtained by Manning (14). The negative estimate of heritability obtained indicated the estimates of genetic variances, listed above, may be of limited value. The frequency distribution curves for total variance of the F_1 and S_1 progenies were bi-modal. Also, the frequency distribution for genetic variance of the S_1 and the mean yield distribution frequencies were bi-modal. These data indicated two populations within each group. Further, the mean yield frequency distribution and the over-all mean of the F_1, S_1 and inbred indicated a heterotic effect for yield in the F_1. It was necessary to assume two populations

within the Stoneville 62 families. The Stoneville 62 plants in one population were probably homozygous for several of the same genes effecting yield as was the inbred parent and heterozygous for others. If the effects of these genes were aditive then selfing such a population and crossing it with an individual homozygous for many of the same genes it carried would produce an S_1 population with a high mean yield and a high variance. The F_1 should have a lower mean yield and a lower variance than the S_1. This would account for the high yield peak and high variance of the S_1 distribution, and would account for the low yield peak and low variance distribution of the F_1 population.

The second population within the Stoneville 62 variety was assumed to be homozygous for some yield factors not carried by the inbred and heterozygous for other, one complement of which were carried by the inbred in a homozygous condition. Such an individual should produce an S_1 progeny having a low yield and a low variance compared to the F_1 which should have a high yield and a high variance. This explanation would account for the 27 families having $\sigma^2_{F_1} > \sigma^2_{S_1} > \sigma^2$ inbred. The variances of the remaining seven families were thought to be the result of sampling errors.

The genetic variances for the four characters studied indicated that homozygosity had not been reached in Stoneville 62. The frequency distributions of genetic variances supported this hypothesis by not following a normal curve. Instead the modal group was always in the low-variance range.

The variances and frequency distributions for the four characters studied indicated most families were homozygous or nearly so. The families having a large genetic variance for one character usually had a low variance for the other three. These findings would indicate the

remaining genetic variance was due to residual heterozygosity and not outcrossing to another variety. Had the population been outcrossed, the families effected would have been heterozygous for several characters and the frequency distributions would not have skewed so far to the left. The high degree of homozygosity estimated for these families and the skewed frequency distributions further indicated the population was close to genetic equilibrium for these four characters studied.

The observed means of the parent varieties were so near the same value that no reliable estimates could be made as to the type of gene action governing the four characters studied.

SUMMARY AND CONCLUSIONS

The residual heterozygosity in two varieties of open-pollinated upland cotton developed in Oklahoma was investigated. The characters measured were Micronaire values (fiber coarseness or fineness), lint per cent, per cent first harvest (earliness), and yield of lint. Two heterozygosity experiments were conducted to determine the amount of genetic variance persisting in each open-pollinated variety. S_1 progenies from 50 plants of an open-pollinated variety, plants of an inbred progeny, and 50 F_1 progenies from a cross of each of the 50 plants of the open-pollinated variety with the inbred were included in each experiment. The hypothesis followed in interpreting these data was: if heterozygosity persisted in the open-pollinated population then the rank of variances would be $\sigma^2_{S_1} > \sigma^2_{F_1} > \sigma^2$ inbred. The estimates of genetic variability were made by subtracting the total variance of the inbred variety from the total variance of each S_1 progeny. This difference was assumed to be genetic.

Two experiments were conducted to study the heritability of the characters studied under conditions existing when the data were taken. One estimate of heritability was made using the inbred varieties and the other using the open-pollinated varieties.

The conclusions drawn from these studies may be summarized as follows:

(a) The Half and Half inbred proved to be so variable that the heterozygosity and heritability tests in which it appeared were not considered reliable.

(b) Stoneville 62 possesses some genetic variability for fiber coarseness, much of which is concentrated in relatively few plants.

(c) Stoneville 62 possesses considerable genetic variability for lint per cent. Several plants had a large genetic variance for this character.

(d) Several Stoneville 62 plants were highly heterozygous for per cent first harvest.

(e) Residual variability for yield persisted in several plants of Stoneville 62.

(f) There appeared to be sufficient genetic variance within Stoneville 62 to make progress for all characters studied. Heritability estimates indicated rapid progress could be made by breeding for fiber coarseness and per cent first harvest; progress would be slow for lint per cent and no conclusion was reached for yield.

(g) There was ample evidence to indicate Stoneville 62 had not reached homozygosis for any of the four characters studied. However, it is probably close to genetic equilibrium for all characters studied.

(h) The fact that plants with large genetic variance for one character usually exhibited low genetic variances for the other characters measured suggests that this partially outcrossed population at or near equilibrium had heterozygosity randomly distributed among plants.

LITERATURE CITED

1. Bilbro, James D. Jr. Comparative effectiveness of three breeding methods in modifying coarseness of cotton fiber. Unpub. Ph. D. Thesis. Oklahoma State University, Stillwater, Oklahoma. 1957.

2. Brinkerhoff, L. A., Green, J. M., Hunter, R., and Fink, G. Frequency of bacterial blight-resistant plants in twenty cotton varieties. Phytopathology. 42:98-100. 1952.

3. Charles, D. R., and Smith, H. H. Distinguishing between two types of gene action in quantitative inheritance. Genetics. 24:34-48. 1939.

4. Comstock, R. E. Theory of quantitative genetics: synthesis. Cold Spring Harbor Symposia on Quantitative Biology. 20:93-102. 1955.

5. Comstock, R. E., Robinson, H. F., and Harvey, P. H. A breeding procedure designed to make maximum use of both general and specific combining ability. Agron. Jour. 41:360-367. 1949.

6. Comstock, R. E., and Robinson, H. F. Analysis of genetic varability in corn with reference to probable effects of selection. Cold Spring Harbor Symposia on Quantitative Biology. 20:127-136. 1955.

7. Green, J. M. Variability in the properties of lint of upland cotton. Agron. Jour. 42:338-341. 1950.

8. Green, J. M. Isolation of cotton for seed increases. Agron. Jour. 45:366-368. 1953.

9. Green, J. M., and Brinkerhoff, L. A. Inheritance of three genes for bacterial blight resistance in upland cotton. Agron. Jour. 48: 45-59. 1955.

10. Humphrey, L. M. Effects of inbreeding cotton with special reference to staple length and lint percentage. Ark. Agri. Expt. Sta. Bul. 387. 1940.

11. Hutchinson, J. B. The application of genetics to plant breeding. I. The genetic interpretation of plant breeding problems. Jour. Genetics. 40:271-282. 1940.

12. Lerner, I. Michael. Genetic Homeostasis. 1st. ed. New York. John Wiley & Sons, Inc. 1954.

13. Lush, J. L. Animal breeding plans. 3rd. ed. Ames, Iowa: Iowa State College Press. 1949.

14. Manning, H. L. Response to selection for yield in cotton. Cold Spring Harbor Symposia on Quantitative Biology. 20:103-110. 1955.

15. Manning, H. L. Yield improvement from a selection index technique with cotton. Heredity 10:303-322. 1956.

16. Mason, T. G. A note on the technique of cotton breeding. Emp. Cot. Grow. Rev. 15:113-117. 1938.

17. Miller, P. A., Williams, J. C. Jr., Robinson, H. F., and Comstock, R. E. Estimates of genotypic and environmental variances and covariances in upland cotton and their implications in selection. Agron. Jour. 50:126-131. 1958.

18. Panse, V. G. 3. Inheritance of quantitative characters with special reference to cotton breeding. Papers and Discussions. A-X-23 Ind. Cent. Cot. Comm. 2nd. Conf. on Cotton Growing Problems in India. 1941.

19. Powers, L. Formulas for determining theoretical effects of certain genetic factors upon inheritance of quantitative characters, with special reference to a study of lycopersicon hybrid. Jour. Agri. Res. 59:555-577. 1939.

20. Powers, LeRoy and Locke, L. F. Partitioning method of genetic analysis applied to quantitative characters of tomato crosses. U.S.D.A. Tech. Bul. 998. 1950.

21. Richmond, T. R. Advances in agronomy. Cotton. IX. Breeding and improvement. New York. Academic Press, Inc. pp. 63-64. 1950.

22. Richmond, T. R. Special cottons for specific end-uses through research. Rayon Textile Monthly 28:373-375. 1947.

23. Robinson, H. F., Comstock, R. E., and Harvey, P. H. Genetic variances in open-pollinated varieties of corn. Genetics. 40:45-59. 1955.

24. Simpson, D. M. Natural cross pollination in cotton. U.S.D.A. Tech. Bul. 1094. 1954.

25. Simpson, D. M., and Duncan, E. N. Effect of selecting within selfed lines on the yield and other characters of cotton. Agron. Jour. 45:275-279. 1953.

26. Snedecor, G. W. Statistical methods. 4th. ed. Ames, Iowa: Iowa State College Press. 1946.

27. Sprague, G. F. Problems in the estimation and utilization of genetic variability. Cold Spring Harbor Synposia on Quantitative Biology. 20:87-92. 1955.

28. Stith, L. S. Heritability and interrelationships of some quantitative characters in a cross between two varieties of Gossypium hirsutum. Unpub. Ph. D. Thesis. Iowa State College, Ames, Iowa. 1955.

29. Warner, J. N. A method for estimating heritability. Agron. Jour. 44:427-430. 1952.

30. Woodworth, C. M., Leng, Earl R., and Jungenheimer, R. W. Fifty genertaions of selection for protein and oil in corn. Agron. Jour. 44:60-64. 1952.

APPENDIX

APPENDIX TABLE I

MEAN VARIANCES OF PROGENIES OF 50 STONEVILLE 62 PLANTS, CROSSES OF EACH OF THE 50 PLANTS WITH INBRED WASHINGTON, AND VARIANCES OF INBRED WASHINGTON AND THE STONEVILLE 62 VARIETY FOR MICRONAIRE VALUES

σ^2 Smaller than Inbreds				σ^2 Inbreds		σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N		N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
				.0392	54	1/			
						2/.0692	70	.1291	82
						+.0984	74	.0874	87
						+.1121	51	.1111	75
						-.0772	62	.1469	60
						-.1008	91	.1664	92
						-.0800	74	.1092	69
						+.1285	59	.0814	76
						-.0641	57	.2546	71
						-.0496	58	.0886	83
						-.0672	39	.1236	42
						-.0496	61	.1554	63
						-.0977	72	.2050	91
						+.0678	65	.0592	67
						-.0836	76	.0856	80
						-.0522	49	.2133	83
						+.1015	74	.0856	67
						+.0767	65	.0761	79
						+.0675	75	.0582	61
						-.0589	35	.0649	78
						-.0724	61	.0925	66
						-.0837	57	.0862	66
						+.1001	44	.0443	78
						-.0742	74	.1379	74
						-.0451	76	.0879	84
						+.0909	74	.0901	77
						+.1795	42	.1583	82
		-.0328	57					.0995	73
						-.0439	83	.0587	61
						+.0703	68	.0700	72
						+.0809	75	.0554	67
						+.0890	65	.0415	68
						-.0749	64	.1153	80
						-.0678	77	.1774	94
						+.1106	55	.1009	99
						+.0910	59	.0662	86
						+.1235	60	.1134	71
						-.1022	92	.1329	76
						-.0684	79	.0907	69

TABLE I (Continued)

σ^2 Smaller than Inbreds						σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N	σ^2 Inbreds	N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
						-.1276	41	.1395	73
						-.0781	53	.1239	86
						-.0880	52	.1328	79
						-.0624	82	.0737	49
						-.1201	79	.1460	53
						-.0692	77	.0713	64
						+.2451	58	.1593	82
						-.0639	46	.0841	72
						+.0893	37	.0779	107
						-.0627	46	.1587	87
						-.0520	59	.1103	77
						-.0618	44	.0847	66

1/- = $\sigma^2_{F_1}$ Smaller than $\sigma^2_{S_1}$ half-siblings

2/+ = $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half-siblings

TABLE II

MICRONAIRE VALUE MEAN VARIANCES OF SELECTED FAMILIES[1/] OF STONEVILLE 62 PLANTS AND THEIR CROSSES WITH INBRED WASHINGTON COMPARED WITH THE VARIANCE OF INBRED WASHINGTON

σ^2 Smaller than Inbreds						σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N	σ^2 Inbred	N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
				.0392	54				
						[2/]-.0692	70	.1291	82
						[3/]+.0984	74	.0874	87
						-.0772	62	.1469	60
						-.1008	91	.1664	92
						-.0800	74	.1092	69
						-.0496	61	.1554	63
						-.0977	72	.2050	91
						+.0678	65	.0592	67
						-.0836	76	.0856	80
						+.1015	74	.0856	67
						+.0767	85	.0761	79
						+.0675	75	.0582	61
						-.0724	61	.0925	66
						-.0742	60	.1379	74
						-.0451	76	.0879	84
						+.0909	74	.0901	77
						-.0439	83	.0587	61
						+.0703	68	.0700	72
						+.0809	75	.0554	67
						+.0890	65	.0415	68
						-.0749	64	.1153	80
						-.0678	77	.1774	94
						+.1235	60	.1134	71
						-.1022	92	.1329	76
						-.0684	79	.0907	69
						-.0692	77	.0713	64

[1/] 60 or more observations in both the Stoneville 62 S_1 and the F_1 hybrid

[2/]- = $\sigma^2_{F_1}$ Smaller than $\sigma^2_{S_1}$ half-siblings

[3/]+ = $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half siblings

TABLE III

MEAN VARIANCES OF PROGENIES OF 50 STONEVILLE 62 PLANTS, CROSSES OF EACH OF THE 50 PLANTS WITH INBRED WASHINGTON, AND VARIANCES OF INBRED WASHINGTON AND THE STONEVILLE 62 VARIETY FOR LINT PER CENT

σ^2 Smaller than Inbreds						σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N	σ^2 Inbred	N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
				3.803	53				
						[2] +5.022	69	4.066	81
3.462	86	-3.276	73						
2.778	74	+3.185	50						
3.525	59	-2.753	61						
						+5.599	89	6.255	89
3.007	68	-2.763	73						
3.725	75					+4.512	58		
3.507	70					+4.848	56		
						+4.343	57	3.805	82
		-3.638	38					4.333	41
3.234	62	-2.135	60						
						[1] -3.994	71	5.522	90
3.326	57					+6.574	64		
2.821	78					+6.240	75		
3.014	82					+8.773	48		
		-3.620	70					6.813	66
3.657	78	-2.790	60						
		-2.989	74					4.635	60
1.649	77	+2.964	34						
						-4.365	60	6.277	65
						+4.926	56	4.738	65
						-4.682	43	4.887	77
						-4.270	59	4.489	73
2.814	81	+2.845	70						
						-4.048	73	8.933	76
						+6.722	41	3.878	81
						-6.006	56	6.386	72
						-4.006	82	4.312	60
2.395	71	+3.147	67						
						-3.836	74	7.277	66
		-3.739	64					6.945	67
						+5.453	62	5.171	77
						-3.828	76	7.573	93
						-4.438	43	5.324	65
						-3.807	54	5.747	98
		-2.206	58					4.933	85
						+5.422	59	4.876	70
2.692	75	+2.806	91						

TABLE III (Continued)

σ^2 Smaller than Inbreds				σ^2 Inbred	N	σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N			$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
2.558	68					+4.436	78		
3.526	72					+4.749	40		
		-1.785	52					4.104	85
						+6.018	57	4.407	78
3.099	48	+3.418	81						
3.644	50	+3.728	78						
3.054	63	-3.045	76						
						+8.224	57	4.292	81
2.591	71	+2.736	45						
3.043	106					+4.110	36		
		-2.025	45					5.928	86
3.436	76	-2.628	58						

1/- = $\sigma^2_{F_1}$ Smaller than $\sigma^2_{S_1}$ half-siblings

2/+ = $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half-siblings

TABLE IV

LINT PER CENT MEAN VARIANCES OF SELECTED FAMILIES[1/] OF STONEVILLE 62 PLANTS AND THEIR CROSSES WITH INBRED WASHINGTON COMPARED WITH THE VARIANCE OF INBRED WASHINGTON

σ^2 Smaller than Inbreds						σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N	σ^2 Inbred	N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
				3.803	53				
						[2/]+5.022	69	4.066	81
3.462	86	-3.276	73			[3/]-5.599	89	6.255	89
3.007	68	-2.763	73						
3.234	62	-2.135	60						
						-3.994	71	5.522	90
2.821	78					+6.240	75		
		-3.620	70					6.813	66
3.657	78	-2.790	60						
		-2.989	74					4.635	60
						-4.365	60	6.277	65
2.814	81	+2.845	70						
						-4.048	73	8.933	76
						-4.006	82	4.312	60
2.395	71	+3.147	67						
						-3.836	74	7.277	66
		-3.739	64					6.945	67
						+5.453	62	5.171	77
						-3.828	76	7.573	93
2.558	68					+4.436	78		
3.054	63	-3.045	76						
2.693	75	+2.807	91						

[1/] 60 or more observations in both the Stoneville 62 S_1 and the F_1 hybrid

[2/]+ $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half-siblings

[3/]- $\sigma^2_{F_1}$ Smaller than $\sigma^2_{S_1}$ half-siblings

TABLE V

MEAN VARIANCES OF PROGENIES OF 50 STONEVILLE 62 PLANTS, CROSSES OF EACH OF THE 50 PLANTS WITH INBRED WASHINGTON, AND VARIANCES OF INBRED WASHINGTON AND THE STONEVILLE 62 VARIETY FOR PER CENT FIRST HARVEST

σ^2 Smaller than Inbreds				σ^2 Inbred	N	σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N			$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
				320.9	51				
270.3	73					1/446.6	69		
254.3	77	-244.3	64						
		-300.0	42					410.2	74
						2/-348.9	52	452.8	49
		-244.0	83					367.0	81
242.7	62					+328.5	63		
		-287.1	56					363.3	62
		-286.3	52					337.4	63
206.8	71					+397.1	48		
						+420.1	33	330.5	36
207.6	59					+400.5	58		
						+500.9	68	337.0	77
317.2	59	-299.4	52						
		-292.7	66					355.5	73
166.0	74					+526.4	40		
		-301.7	72					344.2	66
295.2	78					+321.0	63		
245.0	60	+318.3	73						
297.1	77					+405.4	34		
		-310.4	60					401.5	65
		-308.5	50					376.6	62
289.3	68					+469.9	38		
						-329.2	56	514.8	64
						-359.3	71	432.6	70
						+385.7	62	352.0	68
						+448.5	39	431.1	70
287.7	70	+303.8	47						
255.7	51	+271.1	76						
283.4	65					+344.0	58		
292.3	58	-272.3	66						
						+495.7	53	352.8	64
						-334.6	58	382.7	67
274.2	82	-221.2	73						
230.8	65					+372.8	37		
273.5	84					+492.0	48		
						+424.0	58	339.0	85
272.6	70	+317.7	59						

TABLE V (Continued)

σ^2 Smaller than Inbreds				σ^2 Inbred	N	σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N			$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
		-294.2	91					362.1	75
						+418.6	78	367.2	68
274.9	72					+356.8	40		
239.0	85					+339.0	52		
150.5	78					+328.3	44		
		-320.0	81					456.6	48
220.7	50					+432.2	71		
						+370.6	66	322.0	62
268.3	75	-255.1	52						
		-275.3	42					469.8	58
221.7	95					+465.8	36		
						+356.0	45	337.6	86
285.7	76	-261.9	58						

1/+ = $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half-siblings

2/- = $\sigma^2_{F_1}$ Smaller than $\sigma^2_{S_1}$ half-siblings

TABLE VI

PER CENT FIRST HARVEST MEAN VARIANCES OF SELECTED FAMILIES[1] OF STONEVILLE 62 PLANTS AND THEIR CROSSES WITH INBRED WASHINGTON COMPARED WITH THE VARIANCE OF INBRED WASHINGTON

σ^2 Smaller than Inbreds				σ^2 Inbred	N	σ^2 Larger than Inbreds			
$\sigma^2 S_1$	N	$\sigma^2 F_1$	N			$\sigma^2 F_1$	N	$\sigma^2 S_1$	N
				320.9	51				
270.3	73					[2]+446.6	69		
254.3	77	-244.3	64						
		-244.0	83					367.0	81
242.7	62					+328.5	63		
		-287.1	56					363.3	62
207.6	59					+400.5	58		
						+500.9	68	337.0	77
		-292.7	66					355.5	73
		-301.7	72					344.2	66
295.2	78					+321.0	63		
245.0	60	+318.3	73						
		-310.4	60					401.5	65
						[3]-329.2	56	514.8	64
						-359.3	71	432.6	70
						+385.7	62	353.0	68
283.4	65					+344.0	58		
292.3	58	-272.3	66						
						-334.6	58	382.7	67
274.2	82	-221.2	73						
						+424.0	58	339.0	85
272.6	70	+317.7	59						
		-294.2	91					362.1	75
						+418.6	78	367.2	68
						+370.6	66	322.0	62
285.7	76	-261.9	58						

[1] 60 or more observations in both the Stoneville 62 S_1 and F_1 hybrid

[2] + = $\sigma^2 F_1$ larger than $\sigma^2 S_1$ half-siblings

[3] - = $\sigma^2 F_1$ smaller than $\sigma^2 S_1$ half-siblings

TABLE VII

MEAN VARIANCES OF PROGENIES OF 50 STONEVILLE 62 PLANTS, CROSSES OF EACH OF THE 50 PLANTS WITH INBRED WASHINGTON, AND VARIANCES OF INBRED WASHINGTON AND THE STONEVILLE 62 VARIETY FOR YIELD OF LINT

σ^2 Smaller than Inbreds				σ^2 Inbred		σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N		N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
				201.60	51				
						1/ -319.77	69	358.25	73
						-214.13	64	239.40	77
						-330.17	42	517.71	74
						-370.69	52	399.49	49
						2/ +431.72	83	300.34	81
180.13	62					+471.30	63		
						-215.99	55	305.20	62
						+364.19	52	232.16	63
						+291.48	48	226.80	71
						-319.65	33	325.14	36
						+319.70	58	244.76	59
						-247.51	68	290.22	77
						-321.51	52	372.55	59
						+234.62	66	211.88	73
						+348.15	40	257.57	74
						+378.43	72	352.83	66
189.14	78					+350.82	63		
						+253.61	73	228.51	60
						+332.88	34	242.39	77
137.07	65					+220.39	60		
						+229.03	50	226.11	62
						+373.62	38	286.46	68
182.79	64					+396.05	56		
						+269.73	71	233.03	70
						+362.66	62	231.56	68
						-223.85	39	449.21	70
						+447.52	47	330.96	70
						+364.93	76	295.21	51
						+287.37	58	207.10	65
						-231.62	66	242.08	58
						-344.18	53	475.09	64
						+342.97	58	270.11	67
						+390.96	73	264.56	82
						-327.24	37	340.28	65
						+487.45	48	315.11	84
						+342.49	58	242.71	85
154.74	70					+323.12	59		

TABLE VII (Continued)

σ^2 Smaller than Inbreds				σ^2 Inbred	N	σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N			$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
						-290.42	91	328.71	75
						+345.63	78	305.78	68
						-244.77	40	310.43	72
		-191.72	52					282.92	85
						+372.28	44	353.98	78
166.20	48	+200.56	81						
						+618.19	71	418.55	50
						+386.51	66	217.55	62
						-338.25	52	359.48	75
						+574.35	42	285.31	58
						-212.31	36	229.92	95
						+412.40	45	312.67	86
						+375.17	58	235.01	76

1/ - = $\sigma^2_{F_1}$ Smaller than $\sigma^2_{S_1}$ half-siblings

2/ + = $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half-siblings

TABLE VIII

YIELD OF LINT MEAN VARIANCES OF SELECTED FAMILIES[1] OF STONEVILLE 62 PLANTS AND THEIR CROSSES WITH INBRED WASHINGTON COMPARED WITH THE VARIANCE OF INBRED WASHINGTON

σ^2 Smaller than Inbreds						σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N	σ^2 Inbred	N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
				201.60	51				
						[2] -319.77	69	358.25	73
						[3] +214.13	64	239.40	77
						[3] +431.72	83	300.34	81
180.13	62					+471.30	63		
						-215.99	55	305.20	62
						+319.70	58	244.76	59
						-247.51	68	290.22	77
						+234.62	66	211.88	73
						+378.43	72	352.83	66
189.14	78					+350.82	63		
						+253.61	73	228.51	60
137.07	65					+220.39	60		
182.79	64					+396.05	56		
						+269.73	71	233.03	70
						+362.66	62	231.56	68
						+287.37	58	207.10	65
						-231.62	66	242.08	58
						+342.97	58	270.11	67
						+390.96	73	264.56	82
						+342.49	58	242.71	85
154.74	70					+323.12	59		
						-290.42	91	328.71	75
						+345.63	78	305.78	68
						+386.51	66	217.55	62
						+375.17	58	235.01	76

[1] 60 or more observations in both the Stoneville 62 S_1 and the F_1 hybrid

[2] - = $\sigma^2_{F_1}$ Smaller than $\sigma^2_{S_1}$ half-siblings

[3] + = $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half-siblings

TABLE IX

MEAN VARIANCES OF PROGENIES OF 50 CR-2 PLANTS, CROSSES OF EACH OF THE 50 PLANTS WITH INBRED HALF AND HALF, AND VARIANCES OF INBRED HALF AND HALF AND THE CR-2 VARIETY FOR MICRONAIRE VALUES

σ^2 Smaller than Inbreds				σ^2 Inbred	N	σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N			$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
				.3787	113				
.3049	109	1/ -.2801	100						
.3187	133	2/				+.3889	106		
.2126	104	+.3211	105						
.3441	102	-.3308	87						
		-.3325	93					.4607	112
.2688	79	+.3537	67						
		-.2706	91					.4027	97
.2861	90	+.3199	81						
.1319	95	+.3055	105						
.2026	106					+.4070	87		
.3518	105					+.4925	105		
.3442	110	-.3259	123						
						+.4135	125	.3882	107
.2985	113	+.3098	85						
.1810	84					+.3911	107		
.3610	79	-.2732	110						
.3022	96	-.2739	106						
.3699	118					+.4891	101		
.3184	103					+.4535	97		
.3522	74					+.4192	119		
		-.2770	93					.3802	116
						+.4006	93	.6004	74
						+.3994	86	.4075	95
						+.4248	102	.4502	120
.3165	114	+.3506	103						
		-.3534	109					.3868	99
.2991	110					-.3938	83		
						+.5115	108	.3928	110
.2462	107					+.5321	106		
						+.4456	105	.3915	112
.3024	126					+.3885	117		
		-.3164	112					.4301	96
.2828	91					+.4073	105		
		-.3216	97					.3973	84
.2386	104					+.3903	92		
.2510	107	+.3453	70						
.3363	116	+.3733	103						
.2628	99	+.3225	92						

TABLE IX (Continued)

σ^2 Smaller than Inbreds				σ^2 Inbreds	N	σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N			$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
.2338	106					+.4930	90		
.3125	121	+.3654	106						
.2463	107					+.4769	53		
.2887	97					+.4409	84		
.2895	100	+.3191	105						
		-.3254	86					.4408	106
.2566	99					+.3772	115		
						+.4724	100	.4271	102
.2922	86					+.4319	99		
.2682	84					+.4621	92		
						+.4562	98	.4487	94
.2247	109					+.3790	112		

1/- = $\sigma^2_{F_1}$ Smaller than $\sigma^2_{S_1}$ half-siblings

2/+ = $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half-siblings

TABLE X

MEAN VARIANCES OF PROGENIES OF 50 CR-2 PLANTS, CROSSES OF EACH OF THE 50 PLANTS WITH INBRED HALF AND HALF, AND VARIANCES OF INBRED HALF AND HALF AND THE CR-2 VARIETY FOR LINT PER CENT

σ^2 Smaller than Inbreds				σ^2 Inbred	N	σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N			$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
		1/		2195.150	113				
1260.376	109	-1232.315	100						
		2/-1004.928	106					2238.268	133
3.350	104	+1047.918	105						
8.557	102	-7.075	87						
16.381	112	-5.982	93						
		-1334.749	67					2981.494	79
		-3.599	91					3071.271	97
5.014	89	-2.672	81						
1345.511	95	-5.614	105						
5.482	106	-2.907	87						
3.119	104	+4.275	104						
3.164	110	-2.758	123						
946.644	107					+2690.704	116		
2.953	113	+1550.489	85						
		- 843.480	107					2683.765	84
7.216	79	-4.775	110						
6.934	96	+8.895	106						
1184.001	118					+2499.975	101		
2050.756	103	-3.227	97						
1291.509	74	-4.332	119						
744.867	115	-3.224	93						
3.498	72	-3.174	93						
3.133	95					+2244.925	86		
5.924	120	+1885.092	102						
		-1179.885	103					2929.449	114
3.492	99	+1134.470	109						
926.361	110	-3.450	83						
4.082	110	+4.458	99						
7.073	107	-4.538	106						
899.075	112	-5.669	105						
		-688.430	117					2431.689	126
966.494	96	-912.418	112						
2.012	91	+3.620	105						
46.820	84	+1188.715	97						
		-570.908	92					2220.962	104
2.974	107	+1769.898	70						
4.383	107					+2875.099	103		
2.716	99	-1.886	92						
		-5.165	90					3135.428	106

TABLE X (Continued)

σ^2 Smaller than Inbreds				σ^2 Inbreds		σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N		$\sigma^2_{F_1}$	N		N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
885.753	121	-	6.495	106						
		-	2.532	53					2750.512	107
3.916	97	-	2.948	84						
7.505	100	+	12.894	105						
5.254	106	-	4.497	100						
62.462	86	-	5.757	102						
3.288	86						+4037.723	99		
969.978	115	-	4.590	98						
1410.836	84	+2150.778		92						
972.879	94						+3149.005	98		
935.932	109	+2080.417		112						

1/- = $\sigma^2_{F_1}$ Smaller than $\sigma^2_{S_1}$ half siblings

2/+ = $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half siblings

TABLE XI

MEAN VARIANCES OF PROGENIES OF 50 CR-2 PLANTS, CROSSES OF EACH OF THE 50 PLANTS WITH INBRED HALF AND HALF, AND VARIANCES OF INBRED HALF AND HALF AND THE CR-2 VARIETY FOR PER CENT FIRST HARVEST

σ^2 Smaller than Inbreds						σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N	σ^2 Inbred	N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
				296.85	113				
						[1] -383.7	100	477.2	109
						-575.3	106	626.9	133
						[2] +557.1	105	541.4	104
						-591.7	87	618.9	102
						-1,264.8	93	490.0	112
						-338.8	67	527.5	79
						-578.1	91	2,763.0	97
						+566.8	81	530.9	89
						-426.3	105	518.5	95
						-434.3	87	510.7	106
						+569.2	104	529.6	104
						-406.4	123	437.2	110
						-644.6	116	1,856.4	107
						+672.6	85	464.9	113
						+2,200.5	107	350.5	84
						-625.1	110	660.0	79
						+483.5	106	436.4	96
						-413.8	101	947.5	118
						+477.1	97	322.8	103
						-408.1	119	490.6	74
						-358.0	93	864.1	115
						+491.7	93	484.7	72
						+587.6	86	561.7	95
						-505.0	102	1,660.9	120
						+836.6	103	689.0	114
						+602.4	109	541.8	99
						+498.3	83	470.6	110
						+501.8	108	498.3	110
						-469.0	106	525.6	107
						-395.1	105	594.3	112
						+1,235.7	117	542.8	126
						-875.4	112	1,167.2	96
						-329.9	105	622.9	91
						-435.3	97	529.7	84
						-366.9	92	574.9	104
						-432.9	70	546.5	107
						-389.4	103	452.7	116
						-382.9	92	440.5	99
						-442.8	90	671.4	106

TABLE XI (Continued)

σ^2 Smaller than Inbreds						σ^2 Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N	σ^2 Inbred	N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
						-471.6	106	661.1	121
						+549.9	53	425.4	107
						-525.8	84	582.1	97
						+695.8	105	634.5	100
						+533.8	86	488.8	106
						-296.6	115	557.9	99
						-453.3	100	653.6	102
						+580.4	99	524.7	86
						+436.4	92	390.8	84
						+603.6	98	447.4	94
						+538.3	112	340.6	109

1/ - = $\sigma^2_{F_1}$ Smaller than $\sigma^2_{S_1}$ half-siblings

2/ + = $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half-siblings

TABLE XII

MEAN VARIANCES OF PROGENIES OF 50 CR-2 PLANTS, CROSSES OF EACH OF THE 50 PLANTS WITH INBRED HALF AND HALF, AND VARIANCES OF INBRED HALF AND HALF AND THE CR-2 VARIETY FOR YIELD OF LINT

Variances Smaller than Inbreds						Variances Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N	σ^2 Inbred	N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
				188.61	113				
135.23	109	-126.96	100						
184.89	133					[1]/ +248.08	106		
103.83	104					+199.22	105		
88.90	102					+222.26	87		
113.67	112	+144.25	93						
						+494.52	67	201.28	79
71.77	97					+229.21	91		
124.53	90	+156.71	81						
161.11	95	-141.11	105						
177.14	106					+218.96	87		
111.21	105	+183.69	105						
117.29	110	+145.58	123						
141.13	107	+159.21	125						
98.11	113	+181.02	85						
		-180.63	107					230.78	84
162.85	79	-134.63	110						
76.23	96	+153.64	106						
104.33	118					+205.20	101		
177.18	103					[2]/ +218.03	97		
188.40	74	-139.76	119						
88.31	116					+257.12	93		
124.07	74	+141.59	93						
126.04	95					+347.58	86		
118.61	120	+144.72	102						
180.93	114					+282.15	103		
183.05	99	-153.69	109						
111.74	110					+246.66	83		
142.62	110	-124.78	108						
117.07	107	+146.31	106						
157.26	112	-102.87	105						
		-178.61	117					220.72	126
						+266.15	112	217.20	96
104.09	91	+126.40	105						
93.43	84	+157.26	97						
178.08	104	+183.53	92						
116.09	107	+180.68	70						
129.49	116					+221.75	103		
116.80	99					+192.48	92		
180.45	106					+203.30	90		
143.85	121	+154.36	106						

TABLE XII (Continued)

Variances Smaller than Inbreds						Variances Larger than Inbreds			
$\sigma^2_{S_1}$	N	$\sigma^2_{F_1}$	N	σ^2 Inbred	N	$\sigma^2_{F_1}$	N	$\sigma^2_{S_1}$	N
						+329.72	53	238.43	107
						+233.29	84	192.87	97
86.19	100	+155.91	105						
185.74	106	-139.57	86						
						+257.02	115	192.74	99
		-124.09	100					235.16	102
		- 48.22	99					100.77	86
						+296.91	92	209.27	84
131.94	94					+189.94	98		
134.67	109	+158.99	112						

1/+ = $\sigma^2_{F_1}$ Larger than $\sigma^2_{S_1}$ half-siblings

2/- = $\sigma^2_{S_1}$ Smaller than $\sigma^2_{S_1}$ half-siblings

VITA

Norman Edward Justus

Candidate for the Degree of

Doctor of Philosophy

Thesis: RESIDUAL HETEROZYGOSITY IN TWO VARIETIES OF UPLAND COTTON (*GOSSYPIUM HIRSUTUM* L.) AS MEASURED BY MICRONAIRE, LINT PER CENT, PER CENT FIRST HARVEST, AND YIELD OF LINT

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